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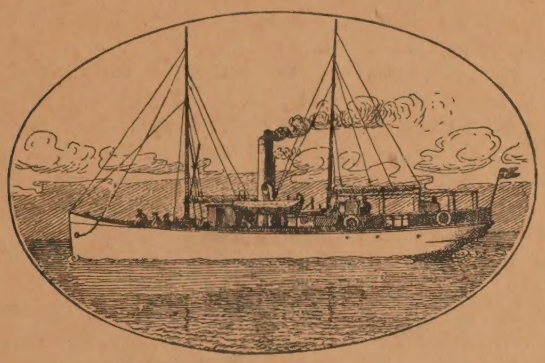
The Danish Biological Station

to

The Ministry of Shipping and Fisheries



XXXV.

1929.

By

A. C. Johansen, Ph. D.
Director.

Copenhagen. C. A. Reitzel.
1929.

The Reports from the Danish Biological Station (Nos. I—XXI) are published in the official Danish "Fiskeri-Beretning" for the years 1890—91 until 1912. After this year they appear as special publications. The Reports I—XXXII are edited by the late Dr. C. G. Joh. Petersen, the Reports XXXIII—XXXIV by Dr. A. C. Johansen.

I. *C. G. Joh. Petersen:* Fiskenes biologiske Forhold i Holbæk Fjord. (1890—91)*) 63 pp. 1 Chart. Out of print.

II. *Idem:* On the Eggs and Breeding of our Gobiidæ. (1891—92.) 9 pp. Two Plates. Out of print.

III. *Idem:* The Pelagic Life in Fænø Sound etc. (1892—93.) 38 pp. Tables. Out of print.

IV. *Idem:* On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. (1893—94.) 146 pp. 2 Plates. 1 Chart. Many Tables. Out of print.

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Etc. 64 pp. Out of print.

VI. *Idem:* The Yearly Immigration of young Plaice into the Limfjord etc. (1895—96). 48 pp. 1 Chart. 2 Tables. Out of print.

VII. *Idem:* Plankton-Studies in the Limfjord. 1897. 23 pp. 1 Map. 4 Tables.

VIII. *Idem:* An Otter-Seine for the Exploration of Deeper-Seas. 1898. 24 pp. With 10 Figures. Out of print.

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XVI. *C. H. Ostenfeld:* On the Ecology and Distribution of the Grass Wrack (*Zostera marina*) in Danish Waters. With 9 figures. 1908. 62 pp.

XVII. *C. G. Joh. Petersen:* II. Second Report on the Oyster and Oyster Fisheries in the Lim Fjord. 1908. (24 pp).

XVIII. *C. G. Joh. Petersen:* I. The Yield of the Limfjord fisheries in recent years and the transplantation of Plaice in 1908. With 6 tables and 1 Chart. II. Biological investigations on the stock of Plaice in the Limfjord. With 3 Tables. III. The Yield of the Prawn fishery from 1885—1907 and its improvement by means of protection. With 3 Tables. 25 pp. 1909.

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XX. *C. G. Joh. Petersen* og *P. Boysen Jensen:* Valuation of the Sea. I. Animal Life of the Sea-Bottom, its food and quantity. With 6 Tables, 3 Charts and 6 Plates. 81 pp. 1911.

*) The figures in ( ) refer to the "Fiskeri-Beretning" for the years quoted.

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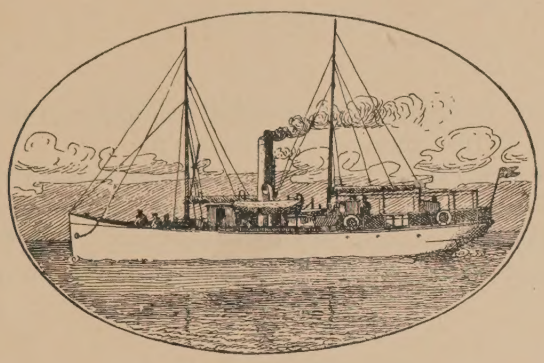

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I.

The Aalborg Herring and its Importance to the Danish Herring Fishery from the XVIth Century until the Present Day.

By

A. C. JOHANSEN

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I. The Herring Fishery in the Limfjord from the XVIth Century until the Present Day.

Whereas the Sound herring occupied a dominant position within the Danish herring fishery from the 12th century until the beginning of the 16th, and throughout the greater part of this period was an important article of merchandise for the commerce of the Hanseatic Towns in northern and central Europe, the herring fishery in the eastern part of the Limfjord began in the course of the 16th century to surpass in importance the fishery in the Sound. In the 16th century the catches of herring in Nibe Broad were of such great importance that the prices obtained for these herring were taken as the standard for the other herring fisheries, and special "salters" were appointed there by the Crown whose duties it was to purchase herring for the royal palaces and the men-of-war. The quantity of herring bought for the King at that time seems to have varied between 50 and 100 lasts per annum, i. e. c. 60 000—120 000 kg. According to D. H. Wulff[1]), on May 23rd 1569 Erik Podebusk was commanded by King Frederik II in a letter to procure 50 lasts of herring for His Majesty's requirements, in addition to the herring previously ordered, and to send them to Copenhagen. Furthermore, in a letter from King Frederik II on March 11th, 1575, Erik Rud received instructions that a salter appointed by the Crown in the fishing villages of Nibe, Sebbersund, Stavn, Øland, Bøll, and Nørholm was to "salt for Us 60 lasts of herring and more for use in Our palaces and men-of-war".

From the time of King Hans the legislature began to concern itself with the herring fishery in the Limfjord, and throughout the entire 16th century a series of regulations dealing with it were issued. In 1515, in the reign of Christian II the employment of pulse-seines (Pulsvaad) in the Limfjord was prohibited by decree, as was also the practice of using such small meshes in the herring nets that the quite small herring were captured along with the larger ones, although they could not be sold in the market[2]). This decree indicates that in addition to the adult herring there were a number of young herring in the Fjord.

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[1]) D. H. Wulff: Bidrag til Limfjordsfiskeriets Historie. Nordisk Tidsskrift for Fiskeri. IV. Copenhagen 1878.

[2]) V. Kiørboe: Om det gamle Limfjords-Sildefiskeri og dets Betydning. Nationaløkonomisk Tidsskrift. III. R. 3. Bd. Copenhagen 1895.

In "Danmarckis oc Norgis Fructbar-Herlighed" from 1656, Arennt Berntsen gives the following description of the fishing village at Nibe (p. 150) "In particular Nibe is a large important fishing village on the shores of the Limfjord, situated a little to the east of the gay and beautiful estate of Lundbeck, famous for the magnificent herring fishery, which is of so great abundance that sometimes, even if the fishery is only moderately productive, not only the surrounding district is supplied with herring at a cheap price but also the larger part of the entire country and other towns situated far away receive many loads and ships' cargoes"[1]).

The most important fishing place for herring was Nibe Broad with the following grounds, Nørlaa, Ølands Grund, Østerland (N.E. of Nibe), and Sebberlaa (Fig. 1). Also farther to the east in the Limfjord were caught considerable numbers of this herring, thus at Gjøl, Nørholm, Aalborg, Mov, Egens, and Hals. In the Deep at Løgstør a number of herring were also caught. The most important spawning places for this herring were in Nibe Broad, and the most important catches were made here in the spring. Also in the autumn the fishery was of some importance and the fish was at this season of the highest quality.

On the more easterly fishing grounds the herring were caught as they were making their way in the autumn and especially in the early spring from the Kattegat in towards Nibe Broad.

Aalborg was of especial importance, owing to its salteries and to its being the market for the Aalborg herring, which were taken from there to many different places in Denmark and the neighbouring countries. According to Joh. Steenstrup[2]), a decree was issued in 1542 prohibiting native and foreign merchants who came to the new fishing villages of Hals, Egens, and Mov from unshipping their merchandise or carrying on trade etc. The citizens of Aalborg received a certain prior right with regard to trading at these fishing villages, according to an agreement entered into by the Crown in 1553, and the villages were under the supervision of the receiver of customs at Aalborg, to whom the dues had to be paid.

The Hanseatic Towns were also interested in the herring fishery in the Limfjord. According to V. Kiørboe (loc. cit.), King Frederik I issued in 1524 a Privilege in which he promised the Hanseatic League to extend the same special fishing rights it enjoyed in Skaane also to other places whither the herring at the time were migrating, viz. Aalborg, Lolland, and Møen. According to D. H. Wulff (loc. cit.), a letter was sent in 1564 from Frederik II to the burgomasters, council, and receiver of customs at Aalborg proclaiming that whereas the burgomasters and councillors at Lübeck had informed His Majesty that some of their fellow burghers had salted some lasts of herring in Aalborg and in other Jutland fishing villages in the neighbourhood but had been prevented from exporting them, His Majesty hereby granted them the right to export these herring and they were therefore to be permitted to pass unhindered, although not without paying tribute to the royal customs.

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[1]) The quotations given here are translated from Danish.

[2]) Johannes Steenstrup: Nogle Træk af Fiskerbefolkningens Historie. Historisk Tidsskrift VII. R. 6. Bd. 3 & 4. H. Copenhagen 1905.

Fig. 1. The Limfjord prior to the breaking through of the Agger Isthmus.
(Prepared by H. P. Simonsen after Videnskabernes Selskabs map from 1790—91.)

At the close of the sixteenth century Aalborg sought to prevent the citizens of Flensborg from fishing for herring and salting at Nibe, but, according to V. Kiørboe (loc. cit.), the King resolved in 1592 that the citizens of Flensborg should be granted the same right to fish for herring everywhere in the country as was enjoyed by the other inhabitants of the kingdom.

The fishery for Aalborg herring has from olden times been subjected to great fluctuations. After having been abundant throughout the greater part of the sixteenth century, the fishery greatly decreased towards the year 1600, which fact is evident from a letter sent by King Christian IV to the Lord Lieutenant (Lensmanden) at Aalborghus in 1601, in which the following remark occurs "since the herring no longer come to Nibe".

In the year 1624 the Agger Isthmus was broken through, whereby, just as later after the breaking through at Agger in 1825, a revolution was caused in the fishery, the stock of freshwater fish in the Fjord being destroyed and a new fishery for plaice, cod, and other saltwater fish arising, whilst the fishery for eels, herring, and Coregonus underwent great changes in the different parts of the Fjord. Arennt Berntsen wrote the following description (loc. cit. p. 164) of the effect of the breaking through of the Agger Isthmus in 1624:

"The North Sea broke in some years ago over this small tongue of land into the Limfjord and made the water salt which had previously been quite or nearly fresh, whereby such great numbers of pike, carp, bream, gwyniads, perch and such fish, which it was formerly rich in, are said to have perished and been washed up on all the shores that hundreds of carts would have been insufficient to take them away. Since that time these kinds of fish have not been present in the Limfjord but only flat fish, eels, whiting, cod, herring, and other salt-water fish which too are by no means of little value but are greatly to be esteemed."

Moreover Arennt Berntsen makes the following mention of the fishery in the Fjord (loc. cit. p. 128):

"Those who live on the shores and occupy themselves there with fishery could obtain rich benefit therefrom, especially those in Nibe and other places along the finest Fjord and the most rich in fish in all Denmark, the Limfjord by name, whither in former times the over-abundant herring resorted and still in general rove in such abundance that therewith not only almost the whole country is cheaply fed but also many ships' cargoes of them are traded to neighbouring lands."

It was the immense herring fishery of Nibe which brought it about that the town in 1699 was granted great trading privileges, and from 1727 the privileges of an incorporate city (Købstad).

Between Aalborg and Nibe there was for a long time great rivalry as to the rights of salting and trading with the herring caught in Nibe Broad. On the ground that Frederik IV by Charter of Dec. 19th, 1727, had conferred upon Nibe Town the privileges of an incorporate city, the citizens of Nibe complained, according to D. H. Wulff (loc. cit.) that several citizens of Aalborg and others carried on fishing

and salting, trade, brewing, and distilling in Nibe and at Sebbersund, whereat the King on June 21st, 1728, ordered the civil governors in Viborg and Aalborg, Iver Rosenkrantz and Chr. Reitzer, to attempt to reconcile the opposing parties, in which, however, they were unsuccessful. The matter ended with the citizens of Aalborg, who claimed ancient privileges granted them by King Frederik II, being still permitted to purchase fish and salt them at Nibe.

We possess several reports from various quarters which afford information as to the yield of the herring fishery in the Limfjord at different periods during the eighteenth century.

According to D. H. Wulff (loc. cit. p. 36), there took place on Feb. 14th, 1715, in the Aalborg Council Chamber "an assembly of burgomasters and councillors, with nine of the foremost merchants and salters, the master of the coopers' guild and four of the guild brethren in order to come to some mutual agreement as to whether the coopers could satisfy the requirements of the salters, who stated that they used approximately 700—1000 lasts of barrels, which, however, was much less than the number used in former times, especially before 1699, when the citizens of Nibe, contrary to all the privileges conferred on the town of Aalborg, were granted a royal Charter permitting them to trade with fish everywhere in the royal dominions and lands, by which the trade and livelihood of Aalborg were greatly injured".

The 700—1000 lasts of barrels must be taken as reckoned only for the salting process carried on at Aalborg, and as the barrels were certainly nearly all whole barrels the salting in the year in question is calculated to have amounted to ca. 10 000 barrels or c. 1 000 000 kg.

Chr. M. Olrik states in his "Afhandling om Aalborgs Handel" ("Treatise on the Trade of Aalborg") from 1773 that the export from Aalborg of salted herring and other fish amounted in 1652 to 305 ships' cargoes, of which 119 cargoes were destined for foreign countries. In the year 1662 the export of fish was smaller, only 36 cargoes being shipped to foreign countries. If we assume with Kiørboe that a ship's cargo comprised on an average 100 barrels, it should be correct to put the export from Aalborg in 1652 at approximately 3 million kilograms. For a series of years more precise information is available as to the amount of salted herring exported:

Exported from Aalborg

	to Denmark	to Norway	to Foreign Countries
1706	1396½ Lasts	272¼ Lasts	1273½ Lasts
1754	525 Lasts 11 Barrels		581 Lasts 3 Barrels
1755	786 — 4 —		369 — 7 —
1756	536 — 11 —	14¾ Barrels	261 — 10½ —
1757	339 — 9 —	2 —	196 — 6
1769	296 — 3½ Quarters	5¾ —	60 —

Converted into barrels and tons (1000 kg.) the aggregate export amounts approximately to the following:

1706	c. 35 300	Barrels	or	c. 3 530	Tons
1754	- 13 300	—	-	- 1 330	—
1755	- 13 900	—	-	- 1 390	—
1756	- 9 600	—	-	- 960	—
1757	- 6 400	—	-	- 640	—
1769	- 4 300	—	-	- 430	—

The mean value of the aggregate export for these six years is thus c. 13 800 barrels or c. 1 380 tons per annum. The export of dried herring ("dry Jutlanders") amounted to between 1 000 and 1 800 barrels per annum for the same series of years.

Johann Ludvig Lybecker in his "Afhandling om det vigtigste Saltvands Fiskerie i Danmark" ("Treatise on the most important Salt-water Fishery in Denmark") (Aalborg 1772) makes the following remarks on the yield of the herring fishery in the Limfjord: "Of merely salted herring, captured in the Limfjord, about 250 000 barrels have passed through the Custom House for exportation in 10 years, namely from 1720 till 1730. This is in addition to the many dried, smoked, and split herring which have been exported; and even in addition to the fresh herring, of which Sweden each spring during this same period has taken an incredible number away in the great open Swedish boats. Yes, in addition to the great number of fresh, smoked and split, dry and salted herring with which Denmark itself has been fed. It is thus no exaggeration if we reckon that the Limfjord in the period mentioned has produced yearly 100 000 barrels of herring" (i. e. c. 10 million kilograms).

According to Chr. Lütken's "Udsigt over de tidligere Fiskeri-Kommissioners Virksomhed og Forhandlinger" ("Survey of the Activities and Negotiations of the former Fishery Commissions")[1]) the decline of the fishery in the Limfjord is discussed in the protocol on the business of the Commission in the years 1740—44 as a fact generally known and unquestioned, and Olrik's statistics quoted above indicate that this decline in the yield continued far into the latter half of the eighteenth century. — In a report from 1771 we find that "since 1750 the abundance of herring has decreased every year so that half of them no longer resort thither as formerly, since they have flocked in such numbers to the Swedish coast."

During the period 1801—28 there occurred again a series of markedly good herring years. To judge from a series of notes by C. Westergaard[2]) dealing with the herring fishery in the eastern part of the Limfjord during the period 1805—17,

[1]) Published by Har. V. Fiedler in "Nordisk Tidsskrift for Fiskeri". Bd. III, 1876. p. 354 et seq.

[2]) Published by Arthur Feddersen in "Nordisk Tidsskrift for Fiskeri" IV. Copenhagen 1878. p. 262 et seq.

the annual average yield of the fishery seems then to have amounted to c. 15 million kilograms, but the information given is too scanty to afford a basis for an accurate calculation. It will, however, scarcely be wrong to assume that the average yield during the period in question amounted to over 10 million kilograms annually.

In his treatise "Om det gamle Limfjordssildefiskeri og dets Betydning" ("The old Limfjord Herring Fishery and its Importance") V. Kiørboe states that in 1817 for exportation alone to foreign countries 38 000 barrels of salted herring passed through the Aalborg Custom House, and in a report made by the town sheriff Bassesen in Nibe on the extent of salting in the Nibe district it is stated that in the same year 37 000 barrels of herring were salted as articles of merchandise. Thus we can reckon with 75 000 barrels of salted herring or c. 7 500 000 kg. from Nibe and Aalborg alone. Kiørboe remarks that the year 1817 is reported as less favourable than the foregoing 12—13 years.

The last great herring year in the Limfjord was 1828, and Kiørboe states that in this year 43 000 barrels of salted herring were exported from Nibe and Aalborg to foreign countries, and 32 000 barrels to Denmark.

During the period from about the middle of the seventeenth century till the year 1825, when the Agger Isthmus was as yet unbroken, the herring fishery in the western part of the Limfjord between Agger and Løgstør was of very little importance. According to Aagaard[1]), only very few herring were caught at Viilsund and in the vicinity of Thy. According to Schade[2]), it was only in a few places that herring occurred in any numbers at Mors. In spring and autumn seines were dragged for herring at Sallingsund where good catches were made in some years, but at Mors not enough herring were caught to render unnecessary the sending of supplies from Nibe.

The statistics relating to the yield of the herring fishery in the Limfjord in the seventeenth century and at the beginning of the eighteenth, which have been mentioned in the foregoing refer exclusively to the herring captured in the eastern part of the Limfjord between Løgstør and Hals. (See Fig. 1).

From 1828 till 1829 a great diminution was observed in the yield of the herring fishery in the eastern part of the Limfjord. The profound effects of the break-through at Agger in 1825 gradually made themselves felt also in the eastern part of the Fjord, and after 1829 the herring fishery in the eastern part of the Limfjord was only of very slight importance.

Table I gives the statistics relating to the yield of the herring fishery throughout the entire Limfjord for the period 1859—1928. For the period 1859—1895 only information as to the yield in terms of value is available but an approximate expression for the yield in terms of weight is given here, being arrived at from price

[1]) Knud Aagaard: Physisk, oeconomisk og topographisk Beskrivelse over Thye. Viborg 1802.

[2]) C. Schade: Beskrivelse over Øen Mors. Aalborg 1811.

quotations from different years within this period, the price for herring being estimated at Kr. 1,00 per Ol (8 kg.)[1]) for the period 1859—1888, and Kr. 1,20 per Ol for the period 1890—95.

Table 1. Total Yield of the Herring Fishery in the Limfjord 1859—1928.

Year	Kroner	Metric Tons	Source
1/4 1859—31/3 1860	39 574	317	Tidsskrift f. Fiskeri IV
- 1860— - 1861	33 236	266	— IV
- 1861— - 1862	51 722	414	— IV
- 1862— - 1863	45 848	367	— IV
- 1863— - 1864	37 478	300	— IV
- 1864— - 1865	30 174	241	— IV
- 1865— - 1866	61 710	494	— IV
- 1866— - 1867	71 906	575	— IV
- 1867— - 1868	54 022	432	— IV
- 1868— - 1869	124 951	1 000	— IV
- 1869— - 1870	94 818	759	— V
- 1870— - 1871	88 074	705	— VI
- 1871— - 1872	88 921	711	— VII
- 1872— - 1873	45 349	363	Nord. Tidsskr. f. Fiskeri I
- 1873— - 1874	47 007	376	— II
- 1874— - 1875	32 582	261	— III
- 1875— - 1876	32 045	256	— IV
- 1876— - 1877	49 608	397	— IV
- 1877— - 1878	36 435	292	— V
- 1878— - 1879	31 032	248	— V
- 1879— - 1880	33 156	265	— VI
- 1880— - 1881	39 366	315	— VII
- 1881— - 1882	45 779	366	Ministerialtidende 1882
- 1882— - 1883	82 147	657	— 1883
- 1883— - 1884	93 757	750	— 1884
- 1884— - 1885	79 808	638	— 1885
- 1885— - 1886	73 055	584	— 1886
- 1886— - 1887	78 684	629	— 1887
- 1887— - 1888	62 608	501	— 1888
1890	62 235	415	Fiskeri-Beretning 1890—91

[1]) In the "Tidsskrift for Fiskeri" and "Nordisk Tidsskrift for Fiskeri" information is given as to the price of herring at Agger in different years within the period mentioned. These herring fetched higher prices than are reckoned with here, i. e.:

In 1872	Kr. 1,95	per Ol (c. 9 kg.)
- 1873	- 1,90	—
- 1874	- 1,78	—
- 1875	- 2,09	—
- 1876	- 1,83	—
- 1878	- 2,33	—
- 1881	- 2,18	—

The herring caught in the North Sea at Agger was predominantly an autumn spawning herring which was caught in the autumn, and the price of autumn herring was generally 1 1/2—2 times as high as the price of spring herring (see Nordisk Tidsskrift for Fiskeri, Bd. V, p. 178).

Year	Kroner	Metric Tons	Source	
1891	70 310	469	Fiskeri-Beretning	1891—92
1892	64 440	430	—	1892—93
1893	71 400	476	—	1893—94
1894	76 420	509	—	1894—95
1895	68 577	457	—	1895—96
1896	76 549	453	—	1896—97
1897	77 230	479	—	1897—98
1898	94 020	636	—	1898—99
1899	92 270	534	—	1899—1900
1900	119 305	528	—	1900—01
1901	142 410	765	—	1901—02
1902	183 485	1 013	—	1902—03
1903	194 765	1 233	—	1903—04
1904	167 460	1 010	—	1904—05
1905	205 948	1 203	—	1905—06
1906	152 950	930	—	1906—07
1907	202 730	755	—	1907
1908	174 640	878	—	1908
1909	134 950	732	—	1909
1910	120 200	524	—	1910
1911	159 450	1 231	—	1911
1912	247 480	2 731	—	1912
1913	268 580	2 350	—	1913
1914	216 750	1 689	—	1914
1915	255 850	1 025	—	1915
1916	625 975	1 061	—	1916
1917	564 930	1 031	—	1917
1918	417 900	844	—	1918
1919	2 340 050	4 067	—	1919
1920	754 260	2 384	—	1920
1921	934 690	3 404	—	1921
1922	428 140	1 988	—	1922
1923	802 990	4 586	—	1923
1924	750 640	3 646	—	1924
1925	939 470	4 165	—	1925
1926	468 560	1 730	—	1926
1927	487 121	1 942	—	1927
1928	335 995	1 901	—	1928

It is clear from Table I that there has been a marked increase in the yield, in terms both of value and weight, during the last decennaries in the Limfjord, and yet the average yield for the entire Limfjord in the last decennary has not exceeded 3 000 tons per annum, or hardly one third of the annual yield in the first quarter of the nineteenth century.

II. The Gears used in the Herring Fishery and the Situation of the most important Herring Grounds prior to the Breaking through of the Agger Isthmus in 1825.

The bulk of the fishery for the Aalborg herring was carried on in Nibe Broad and the adjoining parts of the Limfjord for centuries before the Agger Isthmus

was broken through, and fishing of any importance took place only in the eastern part of the Limfjord between Løgstør and Hals and along a short coastal stretch of Aalborg Bay to the south of the entrance at Hals. This coastal stretch seems to have been of comparatively greater importance as a fishing ground in the 16th and 17th centuries than later, and the fishing village of Dokkedal was visited during the herring season by a number of fishermen. As a sign of Dokkedal's former importance as a fishing village, Kiørboe (loc. cit. 1895) mentions that Mou parish in which Dokkedal lies established its own court of assize (Birketing).

In the writings of C. Westergaard[1]) we find detailed descriptions of the gears used for catching herring in the eastern part of the Limfjord at the commencement of the 19th century. The pound-net was then, as it had been for a long time previously, the most important implement. It was circular, about 28 fathoms in circumference, and with an opening on one side which externally was four fathoms across. From each side of this opening a piece of netting was fixed obliquely, penetrating 3 fathoms into the net, in such a way that the entrance into the net itself was only $^3/_4$ fathom across. The net was fixed, being fastened to piles or so-called "stæg". In the middle of the mouth of this pound-net was fixed a leading net, also fastened to piles and consisting of a piece of netting hanging vertically from a rope or cable.

The pound-net fishery was carried on mostly from March till May and to a lesser extent in the autumn. The most important fishing grounds were the following:

Nørlaa, W. of the channel to Nibe and S. of the channel to Løgstør, also close in front of Nibe to the north-west. Most of the "Stades" were owned by the inhabitants of Nibe, although a considerable number were owned by Sebberkloster, Sebbersund, Waldsted, the salting houses of Lundbæk, and Klitgaard. It comprised 750 stades "and has always been the most important fishing ground in the Limfjord".

Ølands Grund, W. of Klitgaard and N. of Nibe, belonged to Oxholm. It comprised 433 stades.

Østerland, N.E. of Nibe, on the eastern side of the Deep, extends from Nibe down past Klitgaard. It comprised 110 stades which were owned partly by Nibe, partly by Restrup and Klitgaard.

Sebberlaa, 1 mile to the south-west of Nibe. It is connected with the rest of the Fjord by a narrow channel running close past Nibe. It comprised 226 stades and was owned by Sebberkloster, Lundbæk, Sebbersund, and Waldsted.

The pound-net fishery in the Limfjord during the good herring period from 1805—1817 comprised about 130 flat-bottomed sloops "Kaager" for fishing, with 12 nets to each sloop and placed in 6 stades. During periods when the fishing was poor only a comparatively small number of the stades were used.

Seines were employed for fishing predominantly where the ground shelved steeply out towards the deep water. The one end was kept up against the ground

[1]) Reproduced by Arthur Feddersen in "Nordisk Tidsskrift for Fiskeri". IV. Copenhagen 1878. p. 263 et seq.

whilst the other was rowed straight out from the land to the deep water, and was then drawn in the direction from which the current and the herring came. It thereby assumed the form of a crescent and was capable of enclosing herring which accumulated in the pocket. The number of stades where the seines were hawled up was at the beginning of the nineteenth century about 50. The seine was used in the spring and was then the most important fishing implement after the pound-net. The best fishing grounds for the seine were Løgstør Deep and the Deep off Gjøl. Furthermore a number of seines were used farther to the east in the Fjord.

The drift-net was made of fine-spun flax twine. It was rowed out across the current and drifted slowly with it, whereby the herring moving with the current were immeshed. The nets were held upright in the water by wooden floats or small watertight casks fastened to the upper edge and lumps of lead or small stones to the other.

The drift-net fishery was carried on only on the autumn but was then the most important after the pound-net fishery. It was carried on to a fairly great extent from Løgstør and on a large scale from Gjøl and out to sea over a stretch of about 5 Danish miles from Hals. According to Westergaard, the number of drift-net boats at the beginning of the nineteenth century was about 1400—1600.

The fixed gill net was secured in the same way as the drift-net. It was made fast to piles and placed in position on the fishing grounds.

This gear was of less importance and was used especially in September on the pound-net fishing grounds, before the latter fishery commenced. Throughout the entire autumn fishing season it was used in Haurslev Broad, Sebberkloster Broad and in a few places between the pound-nets.

The herring weel was used only to a slight extent at the beginning of the nineteenth century, but previously it had been used more frequently as the fishermen could not afford the expensive pound-nets. It had several pockets and was made fast to piles, the fish being guided into it by means of a leading net.

Information as to the herring and the herring fishery in the western part of the Limfjord between Løgstør and Thyborøn is to be found in Aagaard's "Beskrivelse over Thye" (1802) and Schade's "Beskrivelse over Øen Mors" (1811).

Aagaard reports the following (p. 46): "At Nibe and Løgstør a great number of herring are caught, and many sloops laden with them are brought in here to Thye, where fourscore cost in spring 8—16 skillings (1 sk. = c. $^3/_8$d) and in autumn 28—32 skillings. The herring from the Fjord are better than those caught at sea, and the higher they come up towards Thye and Mors the fatter and better tasting they are, although less plentiful. It is only a very few which are caught at Viilsund and in the vicinity of Thye."

(p. 226): "The herring seine is a large expensive net made of good twisted hemp twine. It consists of two arms, between which there is, as it were, a bag, the so-called "Hov", in which the fish collect. 20—30 fathoms of rope are fastened to each arm. Such a net can cost 60—70 "Rigsdaler" (1 Rdlr. = 2 Kroner), apart from the

boat required for it which costs 16—20 Rdlr. This seine can last for two years or part of it for three. It is mainly herring which are fished with it, although all the other species of fish, such as gwyniads, perch, smelts, etc. may also at times be caught. This fishery begins as soon as the Fjord is clear of ice, and lasts until the end of May. Also since the first herrings are the best the fishermen at Sallingsund have made hauls with the herring seine under the ice. It is in Odsund that the herring mostly occur, wherefore it is customary to fish with 3—4 seines on each side, both at Sund Odde and at Piin Odde. The herring come here for the most part through Sallingsund, for it is only a few that pass through Viilsund on the left side of Mors."

At Jegindø the most important fishery carried on by the inhabitants is for herring and eels: "Herring are caught with the herring seine, commencing in the spring as soon as the Fjord is free of ice, and continuing until May Day."

Schade makes the following remarks concerning the occurrence of herring at Mors (l. c. p. 317):

"At Nykjøbing where there were formerly many herring, gwyniads, pike, perch, trout, etc. there are now no herring at all, and other fish are very scarce."

(p. 319) "Herring are fished with the seine, in spring at Ejerslev, Skarum, and Sillerslev, and in the early and late autumn at Sallingsund where in some years good catches are made; yet not enough herring occur at Mors for it to be possible to dispense with supplies from Nibe."

III. The Distribution and Habits of the Aalborg Herring prior to the Breaking through of the Agger Isthmus in 1825.

As is clear from the foregoing chapter, the herring did not appear in large numbers in the central and western parts of the Limfjord between Løgstør and Agger before the Agger Isthmus was broken through. The herring fishery was in those times of only slight importance in these regions. We may thus reasonably assume that there were then no spawning grounds for herring in the Limfjord to the west of Løgstør as there are now at the present day. The cause of this is probably the low salinity of the water at that time in these parts of the Fjord.

We can in some measure estimate the salinity of the waters around Mors from the Fjord fauna mentioned in Aagaard's: "Beskrivelse over Thye" from 1802, and Schade's "Beskrivelse over Øen Mors" from 1811, which enumerates the following species:

Fish:

Perch (*Perca fluviatilis* L.). Frequent, according to Aagaard.
Ruff (*Acerina cernua* L.). Frequent, according to Aagaard.
Three-spined Stickleback (*Gasterosteus aculeatus* L.).
Ten-spined Stickleback (*Gasterosteus pungitius* L.).

Viviparous Blenny (*Zoarces viviparus* L.).
Plaice (*Pleuronectes platessa* L.). Fairly rare[1]).
Flounder (*Pleuronectes flesus* L.). Fairly rare.
Garfish (*Belone acus* Risso). Extremely rare.
Pike (*Esox lucius* L.). Common, according to Aagaard.
Roach (*Leuciscus rutilus* L.). Frequent, according to Aagaard.
Dace (*Leuciscus grislagine* L.?).
Bream (*Abramis brama* L.). Rare at Mors, fairly frequent in Viil Cove at Salling.
Trout (*Salmo trutta* L.). Common.
Gwyniad (*Coregonus lavaretus* L.). Frequent.
Smelt (*Osmerus eperlanus* L.). Frequent.
Eel (*Anguilla vulgaris* Turt.). Frequent.
Herring (*Clupea harengus* L.). Infrequent.
Sprat (*Clupea sprattus* L.). Infrequent.
Pipe-fish (*Nerophis ophidion* L.). Not rare.
River Lamprey (*Petromyzon fluviatilis* L.). Not rare.

Invertebrates:

Neritina fluviatilis L.
Crangon vulgaris Fabr.
Gammarus sp. Common.
Nereis diversicolor Müll. Rare.
Piscicola sp.
Aurelia aurita Lam. "sometimes drifts up here into the Fjord".

Several of the above species avoid quite fresh water, such as the viviparous blenny, plaice, garfish, herring, sprat, *Crangon vulgaris*, *Nereis diversicolor* and *Aurelia aurita*, and the presence of a species such as *Crangon vulgaris* indicates that the salinity of the water has probably not been less than 5—6 per mille. On the other hand the presence of a species such as the bream indicates that the salinity of the water has probably not exceeded 6 per mille to any appreciable extent.

With respect to the hydrographical conditions in the western part of the Limfjord prior to the breaking through of the Agger Isthmus in 1825, Schade writes as follows (loc. cit. p. 113):

"The rise and fall of the Limfjord is due chiefly to the winds. Easterly and northerly winds produce high water and westerly winds low water, unless there is a storm blowing from the north-west in which case the water is driven into the Kattegat; but the Fjord cannot thereby be brought to rise to any unusual extent since the same storm tends to prevent the water from penetrating into the Fjord

[1]) This species is not mentioned by Aagaard (loc. cit.) as occurring along the shores of the Fjord in Thye, and it has undoubtedly been very rare in this part of the Fjord.

from the eastern side. At times the copious flow from the streams of the surrounding country can also contribute to the rise in the height of the Fjord. The greatest height from its lowest level that it has risen for a period of many years was here $1^1/_2$—2 ft. at Nykjøbing.

The currents are strongest in the Sounds and where it is deepest. They have no proper periodical path but flow now several days in one and the same direction, now for only one or a few hours in the contrary direction and then turn again. At times two currents may be seen flowing in opposite directions simultaneously. The currents are most inconstant and strongest in their movements upon the approach of rough weather."

To this may be added that the Fjord prior to the breaking through of the Agger Isthmus was undoubtedly more often covered with ice than is the case at the present time. On the one hand the Fjord did not receive then as now supplies of relatively warm water from the North Sea in winter, and on the other, water of low salinity freezes at a higher temperature (near Zero) than water of relatively high salinity.

As regards the migrations of the Aalborg herring in the eastern part of the Limfjord, C. Westergaard, a ship-owner with an expert knowledge of fishing, gives the following information in some Observations[1]) written by him in 1829—30 on the occasion of the Royal Scientific Society's (Kgl. danske Videnskabernes Selskab) setting a subject for a prize: "From the middle of May until the beginning of June (the end of the fishery), when the summer heat decays the nets and the herring again for the most part leave the Fjord, they become rather more fat . . .".

"The immigration of the herring begins generally in the middle of September and continues, although interrupted and in shoals, until the end of April, after which they appear to begin emigrating again, especially when great heat sets in early. Towards the end of May the emigration is fairly rapid . . .".

"Probably nothing definite can be said as to the reason of the herrings' regular immigration into the Limfjord in preference to so many other places. We are only told that they come to spawn in the fresher water, but why they have to such a degree chosen the Limfjord no one will take upon himself to explain."

One of the enterprising ship-owners in Nibe Town, interested in fishery, was P. Kold, who wrote in the Aalborg Stifts- og Adresseavis in 1829 the following remarks on the herring in the Limfjord[2]):

"The fresh water, the chief part of which flows into the western part of the Fjord, and which, before communication was established with the North Sea, all passed by Hals out of the Fjord with the outgoing current, made the water almost fresh right up in the Fjord, made it brackish towards the mouth, and produced such a vegetation on the bottom of the Fjord as to enable it to feed the many species

[1]) Nordisk Tidsskrift for Fiskeri, IV, 1878, pp. 348, 349.

[2]) Reproduced by Arthur Feddersen in Nordisk Tidsskrift for Fiskeri, IV, 1878, pp. 259, 260.

of fish which partly lived there and partly entered the Fjord in order to deposit their spawn to be hatched there. Amongst these last species of fish were the herring, which before their emigration in spring deposited their spawn, chiefly upon the green grass growing in great abundance on the bottom of the Fjord, and moreover in such quantities that the blades and stems of grass where the herring lived in the spring became thick and as it were quite glazed with the roe and milt of herring to such a degree that they became 4—8 times as thick as usual. This spawn was hatched at incredible speed in such quantities that already in May, when the adult herring were caught, they were seen swarming out of the meshes of the pound-nets."

In this last observation Kold is in error. The fry he has seen swarming out through the meshes of the pound-nets are not the fry of that year, which in May are quite tiny and pelagic, but the fry of the previous year. It is, however, clear both from this and from several other older reports that in the period before the Agger Isthmus was broken through there were numerous young herring in the Limfjord.

In the old reports there are no accurate descriptions of the situation and extent of the spawning grounds, but there is no reason to doubt that Nibe Broad and the adjacent parts of the Fjord, where the adult herring were caught in the greatest numbers, were the most important spawning grounds, where the roe according to the information in our possession may be assumed to have been deposited on a dense vegetation of *Potamogeton pectinatus*.

From the period before the Agger Isthmus was broken through we do not possess, so far as is known to me, any observation on the salinity of the water in Nibe Broad or in the adjacent parts of the Fjord, where the Aalborg herring undoubtedly had their most important spawning grounds. We may, however, safely assume that the salinity fluctuated greatly here. In calm weather high and low tide were regularly observed to take effect from the entrance at Hals as far as the grounds at Løgstør. The water from the Kattegat of 24 per mille salinity flowed regularly for 6 hours into the Fjord twice every 24 hours, and the water in the Fjord, the mean salinity of which at Løgstør probably did not exceed 8 per mille, flowed regularly for 6 hours into the Kattegat twice every 24 hours. During periods when stormy winds blew from the south the salinity of the water at the herrings' spawning grounds in Nibe Broad probably did not exceed c. 8 per mille, but during periods when north-westerly stormy winds prevailed the salinity probably approached 24 per mille[1]). The mean salinity of the water in the region adjoining Nibe Broad amounted in all likelihood to c. 12—15 per mille.

From olden times the Aalborg herring have probably had spawning grounds along the shores of Aalborg Bay of the Kattegat. The salinity of the water here,

[1]) It is a characteristic feature that another of the most important races of herring in the waters around Denmark, viz. the Sound herring, also for centuries has had its most important spawning grounds in a region where the salinity of the water undergoes great fluctuations, i. e. in the border region between the Sound and the Baltic proper.

before the breaking through of the Agger Isthmus, was without doubt about the same as it is at the present day, i. e. c. 22—25 per mille.

The herring entered the Limfjord only when the water from the Kattegat was pouring into it. When the water from the Limfjord poured out into the Kattegat the full herring remained behind in the Fjord. On the other hand, after the spawning in May or at the beginning of June had come to an end, the spent herring passed with the current out of the Fjord into the Kattegat.

Curiously enough Westergaard was of the opinion that the herring after leaving the Limfjord in May or June made their way out into the Skagerak (or the "North Sea" as Westergaard calls these waters), and from there entered the Limfjord again in the following autumn.

In this connexion Westergaard writes as follows[1]):

"It seems clear that there must have been some reason for only a few herring having entered the Fjord in the autumn fishery [in 1829] now ended, but what is it? We must search for it in the light of experience and of our knowledge of past times and nature. We know that in general a very great immigration of herring takes place from the North Sea, mostly in September. We know that at the same time we usually have frequent storms blowing from the west and that generally herring are caught in abundance throughout the entire Fjord in fixed nets and drift nets. We know that the herring keep at a fairly great distance from the land when the wind and consequently the boisterous waves beat on it. On the other hand we know that when the storms blow from the land and cause smoother and quieter water than at sea the herring when they are present find their way close inshore. What is now more natural than that the herring which come in from the North Sea during the storms which blow at this time are lured past the Skaw on to the flat grounds, carried with the south-going current induced by the same storms along the coast of Jutland, and upon encountering the current which flows strongly past Normandshage at Hals into the Limfjord are carried with it into the new entrance . . ."

As will be clear from the following chapter, we are now in possession of facts which make it seem probable that Westergaard's theories were correct.

IV. The Racial Features and Habits of the Aalborg Herring at the Present Day.

If we fix our attention on the habits of the herring in the eastern part of the Limfjord at the present day, it is evident that they are exactly the same as those of the old Aalborg herring before the Agger Isthmus was broken through in 1825. The herring spawn in Nibe Broad and the adjoining parts of the Fjord in April-May and at the beginning of June. After spawning they emigrate to the Kattegat, especially in May and the first half of June. A smaller

[1]) Reproduced by Arthur Feddersen in Nordisk Tidsskrift for Fiskeri, IV, 1878, pp. 257, 258.

number of herring immigrate into the Fjord from the Kattegat in the autumn, but the bulk of them do not immigrate until the spring, especially in March and April, when the spawning season is approaching.

As the habits of the Aalborg herring of olden times are so completely the same as those of the herring in the eastern part of the Limfjord at the present day, as regards their migrations, spawning season, and spawning grounds, it is natural to assume that we still have the descendants of the old Aalborg herring in the Limfjord, and we will therefore consider more closely the racial features and distribution of this herring.

Analysis of herring caught in pound-nets in Nibe Broad, June 3rd, 1929.

Stage of maturity IV	(Full herring with not quite ripe roe or milt)	8 spec.	
— V—VI	(Herring with roe or milt almost or quite ready for spawning)	165	·
— VII	(Herring which have recently spawned)	38	—

The 203 specimens of maturity V—VII were investigated more closely. Their length was as follows:

	♂	♀	♂ + ♀
20 cm	5	2	7
21 -	15	10	25
22 -	41	33	74
23 -	38	28	66
24 -	18	6	24
25 -	5	1	6
27 -	1	..	1
Total...	123	80	203
Mean length	22,6 + 0,5	22,4 + 0,5	22,5 + 0,5

An age analysis of the scales of 49 specimens gave the following result:

Length in cm. ..		20	21	22	23	24	25	Total	Mean length
Year class	Number of winter rings								
1927	2	1	..	1	..	..	..	2	21,0 + 0,5
1926	3	2	6	13	11	2	1	35	22,2 + 0,5
1925	4	..	..	4	4	2	1	11	23,0 + 0,5
1924	5	..	..	..	1	..	..	1	23,0 + 0,5
Total... ..		3	6	18	16	4	2	49	22,4 + 0,5

The investigation showed that the three-year-old specimens constituted the bulk of the sample. Their mean length was $22{,}2 + 0{,}5$, which corresponds to an average growth of c. 7,5 cm. per annum in the first three years of life.

The number of vertebrae were as follows:

Total number (Vert. S.)		Praecaudal vertebrae (Vert. praec.)		Caudal vertebrae (Vert. caud.)	
Number	Frequency	Number	Frequency	Number	Frequency
53	1	22	11	30	6
54	11	23	79	31	47
55	69	24	92	32	92
56	103	25	21	33	50
57	17	..	..	34	8
58	2	..	..	..	..
n	203		203		203
m	55,64		23,61		32,03
σ	0,77		0,75		0,87
σ_m	0,054		0,052		0,061
σ_σ	0,038		0,037		0,043

The number of keeled scales (K_2) between the ventral fin rays and the anus, and the number of ventral fin rays in both fins were as follows:

Keeled scales (K_2)		Ventral fin rays	
Number	Frequency	Number	Frequency
13	28	16	1
14	103	17	9
15	70	18	184
16	1	19	7
..	..	20	1
n	202		202
m	14,22		17,99
σ	0,68		0,35
σ_m	0,048		0,024
σ_σ	0,034		0,017

We will now consider the results of a series of analyses of spring-spawning herring from the central and western parts of the Limfjord, and investigate the

question as to whether these herring have the same racial features as the above-mentioned sample from Nibe Broad:

Analysis of spring herring caught in pound-nets, Nykjøbing Mors, May 8th, 1916.

Stage of maturity V—VII.

Length in cm.....		21	22	23	24	25	26	27	28	Number	Mean length
Distribution	♂.....	..	2	14	6	18	8	6	3	57	24,8 + 0,5
	♀.....	1	5	18	19	17	11	12	3	86	24,7 + 0,5
	♂ + ♀.....	1	7	32	25	35	19	18	6	143	24,7 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
53	1	20	1	30	2	13	21	17	2
54	2	21	..	31	25	14	89	18	138
55	42	22	4	32	73	15	32	19	2
56	87	23	63	33	41	16	1	20	1
57	11	24	55	34	2	..	..	..	..
..	..	25	19	..	..	..	..	..	..
..	..	26	1	..	..	..	..	..	..
n ...	143		143		143		143		143
m ...	55,73		23,62		32,11		14,09		18,01
σ ...	0,650		0,83		0,75		0,627		0,237
σ_m ..	0,054		0,069		0,063		0,052		0,020
σ_σ ..	0,039		0,049		0,044		0,037		0,014

Analysis of spring herring caught in pound-nets, Nykjøbing Mors, May 27th, 1915.

Stage of maturity V—VI.

Length in cm.....		21	22	23	24	25	26	27	28	Number	Mean length
Distribution	♂.....	3	13	29	25	14	30	16	3	133	24,5 + 0,5
	♀.....	3	26	35	25	13	20	12	3	137	24,0 + 0,5
	♂ + ♀...	6	39	64	50	27	50	28	6	270	24,3 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
54	8	22	20	29	3	13	42	17	7
55	82	23	88	30	12	14	145	18	251
56	155	24	110	31	58	15	78	19	10
57	25	25	44	32	120	16	5	20	2
..	..	26	8	33	68	..	..	..	..
..	..	..	..	34	9	..	..	..	..
n ...	270		270		270		270		270
m ...	55,73		23,75		31,98		14,17		18,03
σ ...	0,666		0,918		0,939		0,701		0,303
σ_m ..	0,041		0,056		0,057		0,043		0,018
σ_σ ..	0,029		0,040		0,040		0,030		0,013

Analysis of spring herring from Struer, April 7th, 1887, according to Heincke [1]).

Stage of maturity V—VI.

Length in cm.	23	24	25	26	27	28	Number	Mean length
Distribution	1	4	6	8	9	2	30	26,0 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventr. fin rays		Anal fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
55	12	22	4	31	4	13	4	16	1	14	1
56	31	23	10	32	13	14	17	18	28	15	1
57	7	24	14	33	10	15	9	20	1	16	3
..	..	25	2	34	3	..	..	..	..	17	12
..	..	..	..	..	..	..	..	..	..	18	11
..	..	..	..	..	..	..	..	..	..	19	2
n ...	50		30		30		30		30		30
m ...	55,90		23,47		32,40		14,17		18,00		17,23
σ ...	0,61		0,82		0,86		0,65		0,53		1,07
σ_m ..	0,087		0,15		0,16		0,12		0,10		0,20
σ_σ ..	0,061		0,11		0,11		0,08		0,07		0,14

[1]) Fr. Heincke: Naturgeschichte des Herings. 1898. Tabellen, pp. 109, 110.

Analysis of spring herring caught in pound-nets in Nissum Broad by Mullerne at a depth of 6 metres, April 26th, 1919.

Stage of maturity III—V.

Length in cm.....	18	19	20	21	22	23	24	25	27	29	Number	Mean length
Distribution ♂+♀.	4	0	8	50	62	39	22	4	1	1	191	22,1 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
54	1	21	1	29	1	12	1	16	4
55	40	22	12	30	4	13	9	17	6
56	107	23	72	31	20	14	84	18	179
57	40	24	77	32	88	15	89	19	2
58	2	25	23	33	58	16	8	..	..
59	1	26	6	34	18	..	..	..	..
..	..	..	..	35	2	..	..	..	..
n ...	191		191		191		191		191
m ...	56,03		23,66		32,36		14,49		17,94
σ ...	0,73		0,90		0,94		0,68		0,35
σ_m ..	0,053		0,065		0,068		0,049		0,025
σ_σ ..	0,037		0,046		0,048		0,035		0,018

Dorsal fin rays						Anal fin rays						Pectoral fin rays	
Unbranched		Branched		Total		Unbranched		Branched		Total		in right fin	
No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
3	7	14	55	17	1	2	4	12	8	15	5	16	31
4	156	15	107	18	46	3	144	13	58	16	46	17	104
5	23	16	24	19	107	4	38	14	86	17	90	18	36
..	..	..	..	20	31	..	..	15	31	18	37	19	3
..	..	..	..	21	1	..	..	16	3	19	8	..	..
n	186		186		186		186		186		186		174
m	4,09		14,83		18,92		3,18		13,80		16,98		17,06
σ	0,39		0,63		0,67		0,44		0,82		0,85		0,67
σ_m	0,029		0,046		0,049		0,032		0,060		0,063		0,051
σ_σ	0,020		0,033		0,035		0,023		0,043		0,044		0,036

Analysis of spring herring caught in pound-nets in the western part of Thisted Broad, Limfjord, Jan. 30th, 1918.

Stage of maturity IV—V.

Length in cm.		21	22	23	24	25	26	27	28	29	30	Number	Mean length
Distribution	♂	..	1	5	4	6	13	16	20	6	..	71	26,6 + 0,5
	♀	1	1	2	7	4	12	10	15	10	2	64	26,7 + 0,5
	♂ + ♀	1	2	7	11	10	25	26	35	16	2	135	26,6 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
54	1	22	6	30	2	12	1	16	2
55	37	23	46	31	30	13	8	17	2
56	78	24	67	32	54	14	63	18	129
57	19	25	15	33	43	15	57	19	1
..	..	26	1	34	6	16	6	20	1
n ...	135		135		135		135		135
m ...	55,85		23,70		32,15		14,44		17,98
σ ...	0,65		0,756		0,87		0,71		0,33
σ_m ..	0,056		0,065		0,075		0,061		0,029
σ_σ ..	0,040		0,046		0,053		0,043		0,020

It is clear from these analyses that the samples from Nykjøbing which have been examined possess exactly the same racial features as does the sample from Nibe Broad. The sample from Struer examined by Heincke also agrees with the sample from Nibe as regards number of keeled scales and ventral fin rays, but the Struer sample might appear to have a slightly higher total number of vertebrae than the Nibe sample. As the difference, however, is 0,26 and the mean error of the difference 0,10, no importance should be attached to this difference.

On the other hand, the sample from Nissum Broad and that from Thisted Broad diverge appreciably from the Nibe sample in possessing a higher number of keeled scales and vertebrae, whereas they themselves are in complete agreement.

The sample from Nissum Broad (April 26th, 1919) shows the following difference in numbers in excess over those of the Nibe Broad sample:

Vert. S.	0,39	mean error of difference	0,076
K_2	0,27	— — - —	0,069

The sample from Thisted Broad shows the following difference in excess over the Nibe Broad sample:

Vert. S.	0,21	mean error of difference	0,078
K_2	0,22	—	—	-	—	0,078

These samples have thus other racial features than the samples from Nibe, Nykøbing, and Struer. They evidently belong to a spring spawning coastal herring which is closely related to the Belt Spring Herring, and which no doubt immigrates from the North Sea in the spring. It may be called here for the present "Thyland's Spring Herring".

If we add together the samples from Nibe Broad, Nykøbing, and Struer which have been examined, we obtain the following values for the characters under investigation which are individually constant:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays		Anal fin rays	
No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
53	2	20	1	29	3	13	95	16	2	14	1
54	21	21	..	30	20	14	354	17	18	15	1
55	205	22	39	31	134	15	189	18	601	16	3
56	376	23	240	32	298	16	7	19	19	17	12
57	60	24	271	33	169	..	..	20	5	18	11
58	2	25	86	34	22	..	..	..	..	19	2
..	..	26	9	35	..	..	..	..	..	..	..
n ...	666		646		646		645		645		30
m ...	55,72		23,66		32,05		14,17		18,01		17,23
σ ...	0,70		0,84		0,88		0,68		0,32		1,07
σ_m ..	0,027		0,033		0,035		0,027		0,012		0,20
σ_σ ..	0,019		0,024		0,024		0,019		0,009		0,14

These analyses afford an index of the Aalborg herring's racial features, and we will now give a series of analyses of spring herring from Aalborg Bay, the adjoining parts of the Kattegat, and the southern Skagerak, in order to investigate whether herring are known to be present in these waters possessing the same racial features as the Aalborg herring.

Analysis of spring herring caught in pound-nets at Hals (at the eastern entrance into the Limfjord), May 20th, 1916.

Stage of maturity III—IV.

Length in cm.	21	22	23	24	25	26	Number	Mean length
Distribution	8	76	96	22	6	2	210	22,8 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
55	68	21	1	29	1	12	1	16	1
56	122	22	11	30	5	13	18	17	4
57	20	23	78	31	39	14	131	18	199
..	..	24	95	32	91	15	55	19	4
..	..	25	24	33	67	16	5	20	2
..	..	26	1	34	7	..	..	..	..
n ...	210		210		210		210		210
m ...	55,77		23,63		32,14		14,21		18,005
σ ...	0,607		0,79		0,87		0,647		0,302
σ_m ..	0,042		0,055		0,060		0,045		0,021
σ_σ ..	0,029		0,039		0,043		0,032		0,015

Analysis of herring caught in pound-nets at Udbyhøj (mouth of Randers Fjord), April 26th, 1915.

Stage of maturity IV—V.

Length in cm. ..		20	21	22	23	24	25	26	27	28	Number	Mean length
Distribution	♂	3	3	32	53	42	13	8	4	..	158	23,4 + 0,5
	♀	1	4	18	45	28	15	10	4	2	127	23,7 + 0,5
	♂ + ♀	4	7	50	98	70	28	18	8	2	285	23,5 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
54	1	22	21	30	11	12	2	16	11
55	94	23	123	31	51	13	35	17	23
56	159	24	96	32	117	14	149	18	249
57	31	25	40	33	91	15	89	19	2
..	..	26	4	34	14	16	10	..	..
..	..	27	1	35	1	..	..	..	..
n ...	285		285		285		285		285
m ...	55,77		23,60		32,17		14,25		17,85
σ ...	0,63		0,897		0,92		0,74		0,47
σ_m ..	0,038		0,053		0,055		0,044		0,028
σ_σ ..	0,027		0,038		0,039		0,031		0,020

Analysis of sample of spring herring caught in purse-seines at Kobbergrunden, Kattegat, October 23rd, 1915 [1]).

Stage of maturity: II—III. (Maturing herrings).

Length in cm.	21	22	23	24	25	Number	Mean length
Distribution	2	14	15	8	4	43	23,5 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
55	7	22	1	31	6	13	5	16	1
56	28	23	13	32	22	14	17	17	4
57	7	24	23	33	14	15	19	18	38
58	1	25	5	34	1	16	2	..	..
..	..	26	1	..	..	..	..	..	..
n	43		43		43		43		43
m	56,05		23,81		32,23		14,42		17,86
σ	0,66		0,76		0,72		0,76		0,41
σ_m ...	0,10		0,12		0,11		0,12		0,063
σ_σ ...	0,07		0,082		0,08		0,08		0,045

Analysis of spring herring caught in purse-seines to the east of Læsø (57° 12′ N.; 11° 19′ E.), Oct. 9th, 1922 [1]).

Stage of maturity: II. (Maturing herrings).

Length in cm.	20	21	22	23	24	Number	Mean length
Distribution	4	16	33	9	2	64	21,8 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
54	1	22	6	30	1	13	2	16	1
55	13	23	22	31	11	14	29	17	6
56	40	24	27	32	25	15	27	18	54
57	10	25	9	33	21	16	5	19	2
..	..	..	..	34	6	..	..	20	1
n	64		64		64		63		64
m	55,92		23,61		32,31		14,56		17,94
σ	0,65		0,85		0,92		0,69		0,50
σ_m ...	0,08		0,11		0,12		0,09		0,06
σ_σ ...	0,06		0,07		0,08		0,06		0,04

[1]) cp. A. C. Johansen: Über die Winterheringe des Kattegats. Wiss. Meeresunters. N. F. Abt. Helgoland. XV. Bd. 1923.

Dorsal fin rays Branched		Anal fin rays Unbranched		Anal fin rays Branched		Total	
No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
13	1	2	6	12	1	15	1
14	11	3	52	13	10	16	10
15	45	4	5	14	28	17	28
16	7	..	..	15	20	18	21
..	..	..	..	16	4	19	3
n	64		63		63		63
m	14,91		2,98		14,25		17,24
σ	0,58		0,42		0,86		0,84
σ_m	0,07		0,05		0,11		0,11
σ_σ	0,05		0,04		0,08		0,07

Analysis of spring herring caught in pound-nets at Frederikshavn, April 23rd, 1918.

Stage of maturity III—IV.

Length in cm.	19	20	21	22	23	Number	Mean length
Distribution	1	14	2	5	1	23	20,6 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S. Number	Freq.	Keeled scales (K_2) Number	Freq.	Ventral fin rays Number	Freq.
55	3	13	2	18	23
56	13	14	12	..	..
57	5	15	9	..	..
58	2	..	..	..	..
n	23		23		23
m	56,26		14,30		18,00
σ	0,81		0,64		..
σ_m	0,17		0,13		..
σ_σ	0,12		0,09		..

Analysis of spring herring caugth in purse-seines, N. W. of Hirshals, at 40 fathoms, depth (c. 57° 45′ N.; 9° 15′ E.), March 6th, 1923[1]).

Stage of maturity III—IV.

Length in cm.	19	20	21	22	23	24	Number	Mean length
Distribution	1	4	16	18	19	7	65	22,1 + 0,5

[1]) cp. A. C. Johansen: On the Summer- and Autumn-spawning Herring of the North Sea. Medd. Komm. f. Havundersøgelser. Ser. Fisk, Bd. VII, 1924, pp. 73—75.

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventr. fin rays		Anal fin rays	
No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
54	4	22	4	30	2	13	17	15	1	15	2
55	11	23	23	31	7	14	29	16	1	16	9
56	24	24	22	32	25	15	18	17	2	17	26
57	18	25	14	33	24	16	1	18	60	18	22
58	8	26	2	34	6	..	..	..	..	19	5
..	..	..	..	35	1	..	..	..	..	..	..
n ...	65		65		65		65		64		64
m ...	56,23		23,80		32,43		14,05		17,89		17,30
σ ...	1,07		0,96		0,97		0,78		0,48		0,92
σ_m ..	0,13		0,12		0,12		0,10		0,06		0,12
σ_σ ..	0,09		0,08		0,08		0,07		0,04		0,08

Analysis of spring herring caught in purse-seines, N. of the Skaw, March 17th, 1915.

Stage of maturity: III—IV[1]).

Length in cm.	20	21	22	23	24	Number	Mean length
Distribution	1	2	1	4	4	12	22,7 + 0,5

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventral fin rays	
Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.	Number	Freq.
..	..	21	1	..	..	..	..	..	..
53	1	22	2	31	1	13	2	17	3
54	0	23	4	32	8	14	6	18	9
55	5	24	4	33	3	15	4	..	..
56	6	25	1	..	..	..	..	..	..
n	12		12		12		12		12
m	55,33		23,17		32,17		14,17		17,75

Analysis of sample of spring herring caught in purse-seines 3 nautical miles N. of the Skaw, Jan. 5th, 1924[2]).

Stage of maturity III—V.

Length in cm.	19	20	21	22	23	24	25	26	Number	Mean length
Distribution	1	2	9	7	9	3	3	5	39	22,9 + 0,5

[1]) Amongst the herring of maturity IV was found a specimen of 21 cm. length with 59 vertebrae (26 + 33), 14 keeled scales, and 18 ventral fin rays.

[2]) A. C. Johansen: On the Summer- and Autumn-spawning Herring of the North Sea, 1924, pp. 67, 68.

The distribution of the variants for vertebrae, etc. was as follows:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventr. fin rays		Anal fin rays	
No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
54	3	21	1	29	1	13	3	18	38	14	1
55	11	22	8	31	4	14	24	19	1	15	3
56	12	23	12	32	16	15	11	..	..	16	6
57	12	24	12	33	10	16	1	..	..	17	10
58	1	25	5	34	6	..	..	..	..	18	13
..	..	26	1	35	2	..	..	..	..	19	4
n ...	39		39		39		39		39		37
m ...	55,92		23,38		32,54		14,26		18,03		17,16
σ ...	1,01		1,115		1,19		0,64		0,16		1,24
σ_m ..	0,16		0,18		0,19		0,10		0,03		0,20
σ_σ ..	0,11		0,13		0,135		0,07		0,02		0,14

It is here at once obvious that the sample from Hals (at the eastern entrance to the Limfjord) has the typical racial features of the Aalborg herring.

The Aalborg herring evidently has spawning places in Aalborg Bay in the vicinity of Hals in addition to those in the Limfjord itself.

The sample from Udbyhøj is closely related to the Aalborg herring. It has no perceptible differences from the latter as regards vertebrae or keeled scales but it has a slightly smaller number of ventral fin rays. The difference in this respect is 0,16 and the mean error of the difference is 0,03. The question as to whether the herring which spawn at the entrance to Randers Fjord and Mariager Fjord differ without exception from the Aalborg herring in possessing fewer ventral fin rays merits further investigations.

An examination of the samples from Kobbergrunden and the region E. of Læsø brings to light at once the fact that they differ perceptibly from the Aalborg herring in possessing more vertebrae and keeled scales, and in other respects. Both samples belong to the race of Belt Spring Herring.

The sample from Frederikshavn has more vertebrae than the Aalborg herring, and probably belongs to another race which has not been sufficiently characterized in the analyses undertaken.

The sample from Hirshals differs perceptibly from the Aalborg herring in possessing a higher total number of vertebrae and fewer keeled scales, and in other respects. This is undoubtedly a herring which spawns in the southern part of the Skagerak.

The two samples taken in the Skagerak to the north of the Skaw on March 17th, 1915 and Jan. 5th, 1924 are very characteristic. They show that in winter in the Skagerak a spring spawning herring is caught which

undoubtedly belongs to the inner Danish waters. The spring herring which spawn in the Skagerak possess a higher total number of vertebrae than these samples.

If we add the two samples together, we obtain the following result:

Vert. S.		Vert. praec.		Vert. caud.		Keeled scales (K_2)		Ventr. fin rays		Anal fin rays	
No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.
53	1	21	2	29	1	13	5	17	3	14	1
54	3	22	10	30	..	14	30	18	47	15	3
55	16	23	16	31	5	15	15	19	1	16	6
56	18	24	16	32	24	16	1	..	..	17	10
57	12	25	6	33	13	..	..	..	..	18	13
58	1	26	1	34	6	..	..	..	..	19	4
..	..	..	..	35	2	..	..	..	..	..	..
n ...	51		51		51		51		51		37
m ...	55,78		23,33		32,45		14,24		17,96		17,16
σ ...	1,01		1,11		1,08		0,65		0,28		1,24
σ_m ..	0,14		0,16		0,15		0,091		0,039		0,20
σ_σ ..	0,10		0,11		0,11		0,064		0,028		0,14

It will be seen that this sample agrees closely with the Aalborg herring. The greatest difference is in respect to the precaudal vertebrae. The difference is here 0,33, but the mean error of the difference is 0,163. It will thus be seen that no real differences can be shown to exist between these herring and the Aalborg herring.

The high value of the mean error (σ) for the vertebrae (Vert. S., Vert. praec. and Vert. caud.) indicates that in the samples from the Skagerak N. of the Skaw there are a few individuals which belong to another race than the Aalborg herring, and this is quite natural as in the Skagerak the young herring of several different races mingle with each other[1]).

There is thus every reason to suppose that the Aalborg herring, just as part of the North Sea Bank Herring, the autumn herring of the eastern Kattegat, and the Kattegat winter herring, stay for a considerable part of the year in the Skagerak to eat the abundant plankton of Euphausids, Copepods, etc. This now makes it possible for us to understand why this herring has played such a great part for centuries in the Danish fishery.

Whereas before the Agger Isthmus was broken through in 1825 the Aalborg herring undoubtedly had no spawning places in the Limfjord to the west of Løgstør, there are now in several spots spawning places in this part of the Fjord, e. g. in Louns Broad and in Skive Fjord. Both here and in Nibe Broad the mean salinity of the water during the herring's spawning period has evidently a higher value than

[1]) See A. C. Johansen, loc. cit., 1924.

in the old spawning ground in Nibe Broad before the Agger Isthmus was broken through.

The mean salinity in those places known to be spawning grounds for the Aalborg herring at the present day varies between c. 20 and c. 25 per mille. The mean salinity in the Aalborg herring's spawning grounds before the Agger Isthmus was broken through probably varied between c. 12 and c. 25 per mille. In giving the latter value it is assumed that the Aalborg herring, also before the Agger Isthmus was broken through, had spawning grounds in Aalborg Bay in the vicinity of Hals.

V. What is the Importance of the Aalborg Herring in Comparison with the other Herring Races in the Limfjord at the Present Day?

Whereas the Aalborg herring, prior to the breaking through of the Agger Isthmus in 1825, was undoubtedly to all intents and purposes the only race of herring in the Limfjord, herring of other races also began to penetrate into the Fjord after the formation of the Agger Channel (and later the Thyborøn Canal). It has already been mentioned (p. 26—27) that the samples, which have been examined, of spring spawning herring from Nissum and Thisted Broads did not belong to the race of Aalborg herring, but to the race of Thyland's spring herring which no doubt immigrate from the North Sea in spring.

Moreover, two races of autumn spawning herring make their way into the Limfjord from the North Sea, viz. the West Jutland Autumn Herring and the North Sea Bank Herring.

The West Jutland Autumn Herring plays only a small part in the fishery in the Fjord. It is fished for on quite a small scale in autumn in Nissum Broad where it is caught as full herring but where its spawning grounds are certainly of no great importance. At some fishing experiments with ring trawl, carried out from the Lifeboat Service Steamer "Vesterhavet" in October and November 1923 in Thyborøn Canal and Nissum Broad from 18 stations, only a single tiny herring larva (9 mm. in length) was caught. This larva was caught in the vicinity of the stony grounds off Gjellerodde on Nov. 26th, 1923, and it is not impossible that it may have drifted into the Fjord from the North Sea, since the West Jutland autumn herring have spawning grounds not very far from the coast at several spots between Bovbjerg and Jammer Bay.

Of the North Sea Bank Herring only the young of the two youngest year classes come into the Fjord. These herring which are found in vast quantities in the coastal belt along the west coast of the Jutland Peninsula from the Elbe to the Skaw make their way at certain times in large numbers into the Fjord, both in summer and in winter. They are caught in the Fjord under the name of "Silding" together with the young herring of the Thylands spring herring, the Aalborg herring, and the West Jutland autumn herring.

Table 2. Catches of Young Herring or "Silding" in the Limfjord, 1919—1928.

Year	District A		District B		Total		Price in Kr.
	Tons	Value in Kr.	Tons	Value in Kr.	Tons	Value in Kr.	per kg
1919	19	3 772	88	17 600	107	21 372	0,20
1920	16	1 600	83	8 290	99	9 890	0,10
1921	14	2 800	28	5 500	42	8 300	0,20
1922	15	750	222	11 100	237	11 850	0,05
1923	110	11 800	1 464	146 350	1 574	158 150	0,10
1924	46	1 840	398	19 900	444	21 740	0,05
1925	380	15 200	418	16 700	798	31 900	0,04
1926	127	7 620	272	10 880	399	18 500	0,05
1927	11	440	380	11 385	390	11 825	0,03
1928	40	1 215	886	35 440	926	36 655	0,04

Table 2 gives a summary, derived from information published in the Fiskeri-Beretning[1]), of the catches of "Silding" in the west and central districts in the Limfjord (Districts A and B) throughout a series of years.

Fig. 2. Districts A, B, and C in the Limfjord.

According to various analyses I have made, it must be assumed that the bulk of these "silding" belong to the race of North Sea bank herring.

Statistics of the yield, in terms both of weight and value, of the herring fishery in different districts in the Limfjord are given in Table 3, A and B, being derived from information published in the Fiskeri-Beretning. District A comprises Nissum Broad, Lavbjerg and Kaas Broads, together with Venø Bay and the waters to the west and north of Mors. District B comprises Sallingsund, Livø, Risgaarde and Louns Broads with Hjarbæk and Skive Fjords, whilst District C comprises the eastern

[1]) Information regarding the catches of "silding" for the years 1924—28 has been kindly placed at our disposal by the Fishery Board.

portions of the Fjord between Løgstør and Hals, i. e. those parts of the Fjord to which the herring fishery was almost entirely restricted during the period prior to 1829 (Fig. 2).

Table 3 A. Yield in tons of the herring fishery in the different parts on the Limfjord, 1890—1928 [1]).

(The figures are taken from the Fiskeri-Beretning, sprats not being included.)

Year	District A	District B	District C	District (B + C)	Total yield
1890	123	182	110	292	415
1891	153	217	99	316	469
1892	140	180	110	290	430
1893	129	208	139	347	476
1894	156	197	156	353	509
1895	175	175	107	282	457
1896	152	184	117	301	453
1897	184	172	123	295	479
1898	268	228	140	368	636
1899	202	227	106	333	534
1900	252	208	68	276	528
1901	286	355	125	479	765
1902	438	440	135	575	1 013
1903	520	361	352	713	1 233
1904	534	342	134 [2])	476	1 010
1905	555	475	173 [2])	648	1 203
1906	506	248	176 [2])	424	930
1907	409	216	130 [2])	346	755
1908	433	366	80 [2])	446	878
1909	379	241	113	354	732
1910	329	126	70	195	524
1911	432	473	326	800	1 231
1912	1 614	893	224	1 117	2 731
1913	1 210	917	223	1 141	2 350
1914	631	880	178	1 058	1 689
1915	411	569	45	614	1 025
1916	429	610	22	632	1 061
1917	339	660	33	692	1 031
1918	368	441	34	475	844
1919	1 538	1 907	622	2 529	4 067
1920	892	1 220	272	1 493	2 384
1921	1 319	1 710	374	2 085	3 404
1922	602	1 258	129	1 386	1 988
1923	1 028	3 200	358	3 558	4 586
1924	1 468	1 962	216	2 179	3 647
1925	1 922	2 045	198	2 244	4 165
1926	778	850	102	952	1 730
1927	789	1 003	150	1 153	1 942
1928	591	1 268	43	1 310	1 901

[1]) The yield in tons from all three districts for the years 1890—95 incl. is calculated from the price, which is estimated at Kr. 1,20 per 8 kg.

For the years 1896—1915 incl. the yield in tons is calculated from the yield in ols (four-scores), 1 ol being estimated to weigh 8 kg.

[2]) The catches of herring with the seine in District C are calculated from the price, which is estimated at Kr. 1 per ol (cp. Fiskeri-Beretning for 1902, 1903, 1909, and 1910).

Table 3 B. Yield of the herring fishery in Kroner in the different parts of the Limfjord, 1890—1928.

(The figures are taken from the Fiskeri-Beretning, sprats not being included.)

Year	District A	District B	District C	District (B + C)	Total yield
1890	18 425	27 320	16 490	43 810	62 235
1891	22 980	32 540	14 790	47 330	70 310
1892	20 950	27 050	16 440	43 490	64 440
1893	19 350	31 150	20 900	52 050	71 400
1894	23 450	29 600	23 370	52 970	76 420
1895	26 300	26 300	15 977	42 277	68 577
1896	30 150	31 200	15 199	46 399	76 549
1897	34 250	26 330	16 650	42 980	77 230
1898	42 800	32 020	19 200	51 220	94 020
1899	34 830	42 640	14 800	57 440	92 270
1900	49 350	53 875	16 080	69 955	119 305
1901	61 400	64 910	16 100	81 010	142 410
1902	82 525	76 110	24 850	100 960	183 485
1903	99 350	59 165	36 250	95 415	194 765
1904	91 680	59 080	16 700	75 780	167 460
1905	97 050	87 298	21 600	108 898	205 948
1906	91 250	38 750	22 950	61 700	152 950
1907	144 600	41 830	16 300	58 130	202 730
1908	76 800	79 840	18 000	97 840	174 640
1909	72 850	47 900	14 200	62 100	134 950
1910	83 600	27 900	8 700	36 600	120 200
1911	86 000	52 450	21 000	73 450	159 450
1912	105 250	111 330	30 900	142 230	247 480
1913	109 900	121 775	36 905	158 680	268 580
1914	81 000	110 850	24 900	135 750	216 750
1915	104 200	141 200	10 450	151 650	255 850
1916	296 575	314 750	14 650	329 400	625 975
1917	255 200	293 350	16 380	309 730	564 930
1918	194 300	203 000	20 600	223 600	417 900
1919	916 750	1 100 300	323 000	1 423 300	2 340 050
1920	231 400	401 650	121 210	522 860	754 260
1921	339 900	457 490	137 300	594 790	934 690
1922	150 300	232 600	45 240	277 840	428 140
1923	196 520	526 430	79 740	606 170	802 690
1924	318 060	370 780	61 800	432 580	750 640
1925	409 700	456 570	73 200	529 770	939 470
1926	225 520	205 740	37 300	243 040	468 560
1927	234 240	198 375	54 506	252 881	487 121
1928	166 535	150 110	19 350	169 460	335 995

It is certain that practically all the herring captured in District C are Aalborg herring.

The bulk of the herring caught in District B are also Aalborg herring. The greater number of the "silding" caught in this district must, however, be subtracted from these figures (see Table 2).

A part of the herring captured in District A also belong to the race of Aalborg herring. It may be assumed that the Aalborg herring caught in certain parts of

District A (Kaas Broad, Venø Bay, etc.) more or less balance the catches of herring of other races in District B.

We may thus assume that if we add together the catches in District B to those in District C we shall obtain an approximate expression for the importance of the Aalborg herring to the herring fishery in the Limfjord at the present day.

Table 4 gives a summary of the prices per kilogram of the herring in the different districts of the Limfjord during the years 1916—1928. It will be seen that within this period there has been a great fall in the price. During the years 1916—19 when a high price level prevailed owing to the great war, prices were 2—3 times as high as they have been for the last 7 years. On an average the herring fetched the highest prices in District C and the lowest in District B. The following are the chief reasons for the prices in District C being higher than those in other districts:

1) Comparatively many herring are caught in District C in the autumn when they are of better quality than in the spring and early summer.
2) In a fairly large town such as Aalborg (which lies in District C) the price of fish is on an average high.
3) The catches in District C have been small in relation to the numbers of inhabitants of the adjoining country.
4) Only small numbers of "silding" are caught in District C, whilst in other districts they play a much greater part.

Table 4. Price in Kroner per kilogram of herring caught in the different parts of the Limfjord, 1916—1928.

Year	District A	District B	District C	District (B + C)	Total
1916	0,69	0,52	0,66	0,52	0,59
1917	0,75	0,44	0,50	0,45	0,55
1918	0,53	0,46	0,61	0,47	0,50
1919	0,60	0,58	0,52	0,56	0,58
1920	0,26	0,33	0,44	0,35	0,32
1921	0,26	0,27	0,37	0,29	0,28
1922	0,25	0,18	0,35	0,20	0,22
1923	0,19	0,16	0,22	0,17	0,18
1924	0,22	0,19	0,29	0,20	0,21
1925	0,21	0,22	0,37	0,24	0,23
1926	0,29	0,24	0,37	0,26	0,27
1927	0,30	0,20	0,36	0,23	0,25
1928	0,28	0,09	0,45	0,11	0,16

As the Aalborg herring are caught mostly at a time when they are about to spawn or have just finished spawning, they are on the whole not particularly suitable for canning. The vast majority are now sold either fresh or smoked, whereas during the fishery's most flourishing period they were mostly salted. Those of the Aalborg herring which are caught in the autumn are of excellent quality and are also used to some extent for canning.

The young of the North Sea Bank herring, which occur in large numbers in the coastal belt along the west coast of Jutland and in the Limfjord, would be suitable for forming a basis for a considerable canning industry. It is clear from Table 2 that the price fetched by "silding" in the Limfjord has varied greatly from year to year. This is due to the fact that we have not yet in Denmark a well developed industry for tinned fish which would be a constant purchaser of the "silding". Most of the "silding" caught in the Limfjord are sold to Norway where they are packed in tins, but Norway only requires "silding" at certain times when its own fishery fails to provide sufficient quantities. When the "silding" cannot be sold to Norway they only fetch a very low price and not infrequently are even thrown back into the sea, after being caught, as valueless. Only a small proportion are utilized as food for trout in the Danish breeding ponds.

The development of a Danish fish-packing industry in the neighbourhood of the Limfjord would receive great support from the circumstance that both in the Limfjord and off the west coast of Jutland there are many sprats which are often caught together with "silding".

Although an intensive fishery for "silding" in the Belt Sea and the western Baltic would threaten to diminish the yield of the fishery for adult herring, an intensive fishery for "silding" off the west coast of Jutland and in the western part of the Limfjord would not endanger any of the Danish herring fisheries.

VI. The Importance of the Fishery for Aalborg Herring in the Limfjord in Comparison with the other Danish Herring Fisheries at Different Times.

From about 1550 till 1828 the fishery for herring in the Limfjord was Denmark's most important herring fishery.

As is shown in Chapter I, the fishery yield at certain times within this period probably constituted about 100 000 barrels, or about 10 million kilograms per year. We possess no aggregate figures for the yield of the Danish herring fishery in our other waters in this period, but I am doubtful whether this yield has exceeded that of the fishery for Aalborg herring alone. The herring fishery in the Belt Sea and the southern Kattegat which at the present day is of great importance played at that time a very small part, and the herring fishery in the Sound had already before the middle of the 16th century declined considerably. Arennt Berntsen's description (loc. cit.) of Danish fisheries in the middle of the 17th century gives us the impression that the herring fishery in the Limfjord was then Denmark's most important fishery, and that the herring fisheries in the other Danish waters were only of local significance.

Table 5 gives a summary, derived from the Fiskeri-Beretning, of the total yield of the Danish herring fishery from 1909 till 1928. If we compare the average annual yield of the fishery in the Limfjord with the average yield of the entire Danish herring fishery for the decennary 1919—1928 we arrive at the following result:

	Weight in tons	Value in Kr.	Price per kg. in Kr.
The entire Limfjord	2 981	824 000	0,28
The Aalborg herring (Dist. B + C)	1 889	505 000	0,27
The whole of Denmark	15 857	5 361 000	0,34

It is clear from the preceeding that the yield of the fishery for Aalborg herring in the Limfjord in the last decennary has constituted about 12 per cent. of the weight and about 9 per cent. of the value of the entire yield of the Danish herring fishery.

In the decennary 1890—99 the yield in terms of value of the herring fisheries in Districts B and C in the Limfjord constituted only about 6 per cent. of the total yield of the Danish herring fishery, and from the information in our possession it may be assumed that this percentage is a good expression for the part played by the Aalborg herring during the period from about 1850 till 1900.

From the information given in Chapter I regarding the yield of the fishery for Aalborg herring from about 1650 till 1828, there is reason to suppose that this

Table 5. Total yield of the Danish herring fishery, 1909—1928.

Year	Weight in tons[1])	Value in Kr.	Price per kg. in Kr.
1909	13 159	2 174 000	0,17
1910	10 115	1 849 000	0,18
1911	17 649	2 357 000	0,13
1912	19 078	2 541 000	0,13
1913	22 267	2 502 000	0,11
1914	18 463	2 366 000	0,13
1915	23 232	4 711 000	0,20
1916	24 226	12 763 000	0,53
1917	21 216	8 629 000	0,41
1918	20 293	9 866 000	0,43
1919	23 028	12 661 000	0,55
1920	14 637	7 715 000	0,53
1921	11 981	4 724 000	0,39
1922	9 108	2 788 000	0,31
1923	16 461	3 807 000	0,23
1924	17 722	5 711 000	0,32
1925	16 312	5 004 000	0,31
1926	11 701	3 332 000	0,28
1927	16 133	3 565 000	0,22
1928	21 484	4 307 000	0,20

[1]) For the years 1909—1915 the calculations for converting numbers to weight have been made according to the following scale:

Herring from the	North Sea	1 ol	8	kg.
—	— Ringkøbing Fjord	1 -	= 6	-
—	— Limfjord	1 -	= 8	-
—	— Skagerak	1 -	= 10	-
—	— Kattegat	1 -	= 10	-
—	— Belt Sea	1 -	= 6	-
—	— Baltic	1 -	= 3	-

fishery at that time afforded a yield in terms of weight which was about half that of the entire Danish herring fishery at the present day, and it seems probable that the total yield of the entire Danish herring fishery at that time was of about the same dimensions as it is at the present day.

This result may perhaps appear improbable to some when they reflect on the comparatively small population of Denmark at that time[1]) and on the fact that the fishing technique of those days was somewhat primitive compared with that of modern times, but it must not be forgotten that the herring then formed a very much more important part of the people's daily food than now, and that relatively very much more importance was consequently attached to the herring fishery than at the present day. The great development of the Danish fishery in the last decennaries has included chiefly the fisheries for plaice and other flatfish, cod, haddock, eels, and mackerel and has only to a lesser degree affected the herring fishery.

VII. The Causes of the Fluctuations in the Yield of the Herring Fishery in the Limfjord.

If we look more closely at the fluctuations in the yield in tons of the herring fishery in the Limfjord, it strikes us at once that there are two kinds of fluctuations; firstly the kind which occurs when the period between two maxima only covers some few years, and secondly the kind which is characterized by there being a relatively large fishery yield in certain periods of many years' duration, and a relatively small fishery yield in other periods, also of many years' duration.

The short periods are well-known in all the places where herring fishery is carried on, and it can in general be shown that they are due to more or less favourable years for the development of the tiny fry. If a very abundant year class makes its appearance it will leave its traces in a relatively large fishery yield for several successive years.

We will now submit to a closer investigation the other kind of fluctuation when the periods are of long duration.

As is clear from the preceeding chapter, the yield of the herring fishery in the Limfjord was very considerable throughout the greater part of the 16th century, but towards its close the yield fell sharply. We have, however, no information as to whether this was a case of there being a long period with a small yield.

Arennt Berntsen who describes the breaking through of the Agger Isthmus in 1624 and gives us information as to the injurious effects on the stock of freshwater fish in the Fjord produced by the salt water pouring in, tells us nothing of the effect of the influx of salt water on the herring fishery. Presumably the channel formed by the water breaking through was rapidly filled up with sand. Arennt Berntsen's reports show that the herring fishery in the Fjord in the middle of the 17th century was on a very large scale (see p. 8). The same is evident from the fact, men-

[1]) Even so recently as 1801 the population of Denmark was only 929 000.

tioned by Olrik, that the export from Aalborg of salted herring and other fish amounted in 1652 to 305 ships' cargoes.

In the first third of the 18th century the yield of the herring fishery in the Limfjord was very great, probably amounting at one part of the period to about ten million kilograms per year. There then followed a period of about 40—60 years' duration with a considerably smaller yield.

During the years 1801—1828 the yield of the herring fishery in the Limfjord was again very large, on an average probably about ten million kilograms per year. After 1828 the yield sank for many consecutive years to far less than half a million kilograms per year, but again later in this century increased considerably. In the course of the last decennary the yield of the fishery for Aalborg herring thus approached 2 million kilograms per year (see p. 40).

Only one of the above-mentioned great fluctuations in the yield of the herring fishery in the Limfjord can apparently be due to great changes in natural conditions in the Fjord, i. e. the fluctuation which took place shortly after the Agger Isthmus was broken through at Agger on Feb. 3rd, 1825. The channel formed by the breaking through was originally quite narrow and the Aalborg herring seemed to have used Nibe Broad as their favourite spawning ground until the spring of 1828. Not until 1829 did the catastrophic fall occur in the fishery yield.

The channel at Agger gradually widened, and in 1835 the first ship sailed through it. In 1841 its width was c. 500 metres, in 1849 c. 870 metres. Navigation through the channel reached its climax in the middle of the Fifties of the past century when its depth was about 2,5 metres. After this the depth decreased fairly quickly; in the middle of the 'Sixties navigation ceased, and in the middle of the 'Seventies the channel filled up completely with sand. However, a new channel through the Agger Isthmus was formed at Thyborøn in 1863 after a high sea. This channel rapidly widened and from the middle of the 'Sixties took the place of the more northerly channel at Agger as the path for navigation. Thyborøn Canal was later deepened and made more secure so that it gradually acquired a fairly stable character.

The hydrographical and biological conditions in the Fjord changed greatly after the breaking through of the Agger Isthmus. — Before the latter was broken through the salinity in the western part of the Fjord between Løgstør and the Agger Isthmus was extremely low. As mentioned above (p. 16—17), from information given by Aagaard and Schade respecting the fauna, we can put the salinity of the waters around Mors at the beginning of the 19th century at 5—6 per mille.

After the break through the salinity in the Fjord greatly increased, first and foremost in the western part of it. North Sea water, of salinity c. 33 per mille, made its way in through the Agger channel, and the salinity of the water gradually became higher in the western than in the eastern part of the Fjord.

At the present day the mean salinity of the water around Mors is about 23—28 per mille[1]).

[1]) Aage J. C. Jensen: Remarks on the Hydrography of the Limfjord. Report XXXIV of the Danish Biological Station. 1928.

In Nibe Broad and the adjacent parts of the Fjord where were the herring's most important spawning grounds before the Agger Isthmus was broken through, the mean salinity probably did not exceed 10—15 per mille but was subjected to very great fluctuations. The mean value in these regions is now c. 23—24 per mille, and the salt content varies far less than formerly.

A change in the salinity such as this exerts a radical influence both on the vegetation and the animal life in the Fjord, and it is not surprising that also the herring stock was affected by this change.

The changes in the vegetation on the bottom of the Fjord, which took place after the breaking through of the Agger Isthmus, in Nibe Broad and the adjoining parts of the Fjord do not seem to have been described by any naturalist, but the ship-owner and merchant P. Kold in Nibe, who had expert knowledge of the fishery, writes of it in 1829 in the "Aalborg Stifts- og Adresseavis"[1]): "owing to this salt water [from the North Sea] the freshwater fish in the Fjord have nearly died out, as their spawn cannot be hatched, and this salt water has at length destroyed the vegetation on the bottom of the Fjord which was needed by the herring, except just in the vicinity of the freshwater streams, such as Haldkjæraa and Kyøaa, which discharge into the so-called Sebber-Kloster Bay, and the lack of this vegetation prevents the herring spawn from being hatched."

There is reason to suppose that the vegetation Kold here alludes to was chiefly *Potamogeton pectinatus*[2]).

One asks involuntarily — what happened to the Aalborg herring after 1828 when they ceased to enter the Limfjord in large quantities? — To this the reply may be made that when the old spawning grounds in the eastern part of the Limfjord were spoilt the herring undoubtedly attempted to find suitable spawning grounds elsewhere, and if they were unsuccessful in this a great decrease in their number would occur. We possess evidence that shortly after the cessation of the great herring fishery in the Limfjord the herring fishery in Aalborg Bay to the south of Hals increased considerably. Henrik Krøyer[3]) thus report as follows with respect to the herring fishery in Aalborg Bay to the south of the entrance into the Limfjord:

"A considerable influence is exerted on the fishery in Dokkedal and Mulbjærg by the fact that just as these fishing grounds are enclosed towards the east by shallows they are cut off towards the west by the trackless moor (the Vildmose) from the neighbouring parishes of Nørre- and Søndre-Kongerslev, and Bælum, where would be their most natural markets. Also to sail with the catches to Aalborg

[1]) Reproduced by Arthur Feddersen in Nordisk Tidsskrift for Fiskeri. IV. Copenhagen 1878, p. 260.

[2]) According to C. H. Ostenfeld, this species is met with at the present day throughout the whole of Randers Fjord in water of salinity c. 0,2—22 per mille. "Randersdalens Plantevækst", Randers Fjords Naturhistorie. Copenhagen, 1918.

[3]) Henrik Krøyer: Prøve af en historisk-statistisk Udsigt over de danske Fiskerier. Tidsskrift for Fiskeri. Bd. III. Kjøbenhavn 1869, p. 17.

is rather difficult since the west wind which produces the best fishing blows directly from Aalborg. In 1828, or towards the time when the herring fishery in the Limfjord ceased, only the largest estates in the district, Egense-Kloster, Høstmark, and Vildmosegaard, possessed one pound-net each, and two farmers in Egense shared one. But a year or two later when the herring fishery was found to have definitely come to an end there were 24—26 pound-nets between Egense and Knarmose Grund...."

Krøyer states that the fishery was encouraged by the fact that both pound-nets and sloops could be bought in the Limfjord at low prices, but it seems probable that the great improvement in the fishery also indicate an increase in the number of herring.

We do not know for certain whether there was a comparatively large increase in the numbers of full herring along the coasts of Aalborg Bay during those periods in the 16th and 18th centuries when the herring fishery in the Limfjord was comparatively small, but we possess evidence to the effect that in the 16th century the herring fishery along the stretch of water from the mouth of the Limfjord to Muldbjærge and Dokkedal was considerable. Dokkedal which is now a little village was at that time, as mentioned above (p. 14), a fishing village of importance.

One might therefore assume that an explanation for the periods mentioned when the yield of the herring fishery in the Limfjord was relatively small, lay in the fact that the Aalborg herring had abandoned their spawning grounds in Nibe Broad to a great extent and chosen others off the shores of Aalborg Bay in the Kattegat. This explanation does not, however, hold good when confronted with the conditions now prevailing. A herring fishery of some importance is now carried on, it is true, off the shores of Aalborg Bay along the entire stretch of water from Stensnæs to Stavnshoved in Djursland, but the entire yield of this fishery hardly reaches a million kilograms per year. Furthermore, not all the herring caught in this region belong to the race of Aalborg herring. In recent years about 300 pound-nets have been set out off the shores of Aalborg Bay for the capture of herring and mackerel, and there is no stretch of water of any extent without this effective fishing implement.

It is clear that the intensity with which the fishery is carried on influences the yield. In general the fishery yield increases with the number of fishing gears or with the improvement in the fishing material, but the fishery can also be carried on so intensively that the stock of fish is weakened thereby and the yield sinks.

We cannot summarily reject the possibility that the three periods when the yield of the herring fishery was comparatively small, viz. the end of the 16th century, the middle of the 18th century, and the period 1829—1900, may be explained as a result of "over-fishing", similar to the modern "over-fishing" which occurs in many places, e. g. with respect to the plaice stock in the Belt Sea. There can be no doubt that the herring fishery in the eastern part of the Limfjord was carried on with far greater intensity during the period from about 1550 till 1828 than at the present day. We possess no statistics as regards the number, kind, and size of the

fishing implements used in the 16th, 17th, and 18th centuries, but Westergaard's Survey from the beginning of the 19th century shows a great excess in fishing material over that of the present day. According to Westergaard[1]), there were about 1560 herring pound-nets in the eastern part of the Limfjord from about 1805 till 1817. In the official Danish Fiskeri-Beretning for 1927 the number of herring pound-nets in this part of the Limfjord (District C) was given as 230. According to Westergaard, at the beginning of the 19th century there were about 1500 drift-net boats in the Limfjord. Now the drift-net is to all intents and purposes no more used in the Limfjord.

It is, however, improbable that the great decline in the yield of the herring fishery which began in 1829 and continued for the rest of the century was due to "over-fishing", since this decline took place suddenly and was for a long time of a permanent nature. As mentioned above, it was probably due to the changed natural conditions in the Fjord, which were brought about by the breaking through of the Agger Isthmus in 1825. On the other hand there is a distinct possibility that the comparatively small fishery yield obtained in about the middle of the 18th century was due to "over-fishing". So far as we can judge from the information in our possession the yield at that time decreased gradually. It was already perceptible in the Seventeen-thirties and continued at least until the beginning of the Seventeen-seventies (se pp. 9, 10). According to Chr. Lütken (loc. cit.), the opinion was generally held by the members of the Limfjord Commission of 1740 that the decline in the yield was due to the use of certain implements, such as the "sand seine", "krat seine", and "glib", — and partly to the abuse of "pulse seine". In all probability, however, the pound-net, herring seine, and drift-net were the most important at that time, but the prohibition of these important implements was not to be thought of.

It is scarcely possible at the present day to judge whether the small yield of the herring fishery at the close of the 16th century was due to a temporary "over-fishing". Perhaps the period of small fishery yields was of fairly short duration so that it can be explained by unfavourable conditions for the development of the fry (lack of suitable food for the larvae, etc.) prevailing for several consecutive years.

The considerable rise in the fishery yield in the Limfjord in the last decennaries has been undoubtedly due first and foremost to an increase in the herring stock, both as regards the Aalborg herring (Districts B and C, Fig. 2) and the other herring races in the Fjord (District A, Fig. 2). But the rise is also due in no small measure to the fact that it is gradually becoming possible to make use of young herring ("silding"), which to some extent are caught with an implement which had not previously been employed in the herring fishery in the Fjord, the so-called "cod-seine", which is used in the same way as the Danish seine ("Snurrevaad"). The equipping of many fishing vessels in the last decennaries with motors has also ad-

[1]) Reproduced by Arthur Feddersen in Nordisk Tidsskrift for Fiskeri IV. 1878. pp. 263—271.

vanced the development of the herring fishery, one reason amongst others being that the pound-nets can now be handled far more rapidly and easily than hitherto.

The sharp rise in the price of herring caused by the great demand for articles of food during the war and immediately after it naturally stimulated the fishery and helped to make the yield from about 1916 till 1920 relatively large.

It will be of interest to investigate whether the periods in which abundant herring yields have been observed in the Limfjord coincide with the periods in which the herring fishery off the coasts of Bohuslän has been abundant. These latter periods have been dealt with by, amongst others, A. W. Ljungmann[1]) and Otto Pettersson[2]), and the figures arrived at by these investigators are given here for comparison with the periods observed in the Limfjord.

The Coasts of Bohuslän.

Periods of abundant fishing	Periods of bad or moderate fishing
	1897—1929
1878—1896	
	1809—1877
1748—1808	
	1699—1747
1643—1698	
	1587—1642
1531—1586	

The Limfjord.

Periods of abundant fishing	Periods of bad or moderate fishing
	1829—1900
1801—1828	
	ca. 1740—1770
ca. 1650—1730	
	ca. 1590—1600
ca. 1500—1590	

It will be seen that the two periods of abundant herring fishery in the 16th and 17th centuries coincide in these two regions to a considerable degree, whereas the later periods do not coincide. No closer connexion between the periods in the two regions was to be expected, as the Aalborg herring and the Bohuslän herring

[1]) A. W. Ljungmann: Bidrag till lösningen af frågan om de stora sillfiskenas sekulära periodicitet. Nordisk Tidsskrift for Fiskeri, V, 1879.

[2]) Otto Pettersson: Om det Bohuslänska sillfiskets periodicitet. Svenska Hydrografisk-Biologiska Kommissionens Skrifter. VII, Stockholm, 1922.

(North Sea Bank Herring) belong to two entirely different races, of which the former is indigenous to the Danish coastal waters and the latter to the North Sea.

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II.

Mortality among Animals of the Littoral Region in Ice Winters.

By

H. BLEGVAD

In winters when a continuous hard frost prevails numbers of animals are killed in the littoral region; this is seen most clearly at ebb tide in the case of the clusters of *Mytilus* on the bulwarks and piles where at the end of the frost period mussels are to be found in thousands, with decaying soft parts in the gaping shells, all killed by the cold. It was to be expected that also in the shallow water along the coasts a number of bottom animals would be killed by the cold, but no detailed reports dealing with this subject are available[1]); in the following I will therefore report some observations I made in this connexion in the winter of 1928—29.

According to "The State of the Ice in Danish Waters during the Winter of 1928—29" (Nautical-Meteorological Annual) by the Government Meteorologist Commander Speerschneider, the mean amount of cold (the product of the mean temperature during the frost period and the number of days) for 6 stations distributed over the whole country (Fanø, the Skaw, Hesselø, Bogø, Copenhagen, and Hammershus on Bornholm) during the following winters amounted to:

1906—07	1907—08	1908—09	1909—10	1910—11	1911—12
121.1	65.8	151.6	37.9	23.9	128.6
1912—13	1913—14	1914—15	1915—16	1916—17	1917—18
31.9	49.2	66.3	68.2	169.5	79.4
1918—19	1919—20	1920—21	1921—22	1922—23	1923—24
65.2	64.3	11.3	165.4	57.5	238.8
1924—25	1925—26	1926—27	1927—28	1928—29	
27.9	94.4	21.8	110.3	266.7	

The winter of 1928—29 was thus the coldest in Denmark for the above period; also the number of days with ice in 1928—29 was unusually large (an average of 62.3 for all stations), the average for the whole period being only 19.8. But the most striking feature in the winter of 1928—29 was the fact that there was only one

[1]) There is however in the Aarsberetn. vedk. Norges Fiskerier for 1924, 1. Hefte, an article by Alf Dannevig on Mortality among Fish (Cod, Eel) and Lobsters in severe winters.

continuous ice period, viz. from the middle of January till the end of March; it was thus for Danish conditions unusually severe and protracted and was therefore very suitable for the purpose in view, i. e. the investigation of the effects of a single ice period on the animals of the littoral fauna.

The observations mentioned in the following were made for the most part after the ice period had come to an end; it was only at Nyborg that the conditions were investigated at the same spot on several occasions both during and after the actual ice period.

I. Nyborg Fjord.

The formation of ice commenced here on January 29th 1929. By February 4th the Fjord was covered with heavy fast-ice which not until March 15th became heavy drift-ice; on March 23rd scattered drift-ice was reported, and finally on March 26th the Fjord was free from ice. The thickness of the ice was found by measurement to be: on February 1st, 13 cm., on February 4th, 24 cm., on February 21st, 40 cm., and on March 1st, 55 cm. (Speerschneider, loc. cit.).

The investigations, which were repeated periodically, were carried out on a sandbank where the mean water level was c. 10 cm., at "Avernakke" near the Biological Station's anchorage ground. Here the following observations were made.

February 4th 1929. The sandbank had lain dry for 4 days and was covered with a sheet of ice 20—30 cm. thick. Dug up a square of half a sq. metre. Under the ice the top layer of sand was found to be frozen down to a depth of 15 cm. In this were found *Nereis diversicolor*, all of which were frozen stiff; some of them revived however later after being placed in an aquarium containing freshly procured salt-water at 2—3° C., but they all died within two or three days. In the layer under the frozen sand were found large *Mya arenaria*, not frozen stiff but with prolonged and relaxed siphons, to all appearance lifeless; the upper ends of the siphons reached as far as the bottom of the frozen sand layer. Only about 20 % however of the *Mya* were yet dead, the soft parts being decayed and evil-smelling; the remainder were either quite alive and fresh or had relaxed siphons as mentioned above; the latter however after being placed in aquaria still showed signs of life (the siphons diminished in length), but half of them died in the course of two or three days whereas the remainder were still living several weeks later in the aquaria. Still lower down, c. 40—50 cm. below the surface were found 3 large *Arenicola marina*, alive and fresh.

February 19th 1929. The ice was 40 cm. thick; a hole half a square metre in extent was cut, but it was high tide and the water was 30 cm. above the bottom so that a quantitative investigation was impossible. Many dead *Nereis diversicolor* were seen in the water and the siphons of 4 large, dead, and decayed *Mya arenaria* protruded out of the sand.

February 21st 1929. Low water, sandbank dry. Temperature of the air — 6° C., of the ice — 0.2° C., of the water 0.1° C. One sq. metre dug up. The following temperatures were found in the sand:

On the surface	+ 0.1° C.
At depth of 10 cm.....	0.6° -
- - - 20 -	0.8° -
- - - 40 -	0.8° -
- - - 60 -	1.0° -
- - - 80 -	1.2° -

The temperature in the sand could not be measured at a greater depth owing to the water entering.

At 0—5 cm. below the surface were found *Nereis diversicolor*, *Cardium edule*, *Macoma baltica*, and small *Mya arenaria*; about 80 % of the two former species were dead and on the point of decaying; of the two latter species only about 30 % were dead and decayed, the remainder being still alive.

Of *Arenicola marina* 1 specimen was found dead 10 cm. below the surface, 17 at 15—30 cm.; of the latter 6 were still alive but very relaxed, and 11 were dead. 40 cm. down in the sand on the other hand was found 1 specimen alive and fresh.

At 15—30 cm. below the surface were found 14 large *Mya arenaria*, of which 9 had long relaxed siphons. Of *Nereis diversicolor* at this depth c. 50 % were dead, whereas all the *Macoma baltica* were alive.

In all, the mortality in the area dug up was as follows:

Mytilus edulis	c. 100 %
Littorina littorea	- 100 %
Cardium edule	- 80 %
Nereis diversicolor....	- 70 %
Arenicola marina.....	- 63 %
Mya arenaria.....	- 50 %
Macoma baltica	- 23 %

After the Fjord had become free from ice on March 26th, the temperature of the water being 2° C., a series of samples were taken with the bottom sampler (0.1 sq. m.) along a jetty in close proximity to the same spot. For great stretches along the coast the surface of the bottom was covered with dead and decaying *Nereis diversicolor*.

At 0.4 m. depth (mean water level) were seen c. 80 dead *Nereis* per sq. metre of surface. The bottom sampler gave to 0.1 sq. metre: Dead and decayed: 4 *Mytilus edulis*, 4 *Macoma baltica*, 2 *Mya arenaria*. Alive: 2 *Nereis diversicolor*.

At the same depth but a little farther out: c. 70 dead *Nereis* per sq. metre. B.S.: Decayed: 1 *Mytilus*, 1 *Macoma balt.*, 1 small *Mya aren.* Alive but in very bad condition: 1 *Macoma balt.*, all per 0.1 sq. metre.

At 0.6 m. depth: c. 50 dead *Nereis* per sq. metre. B.S. 0.1 sq. metre: Decayed: 10 *Mytilus*, 1 *Mya aren.*, 2 *Card. edule*. Still living but with decayed hinder end: 8 *Nereis div.*

At the same depth but a little farther out: c. 25 dead *Nereis* per sq. metre. B.S. 0.1 sq. metre: Decayed: 2 *Mytilus edulis*, 1 *Card. ed.*, 1 *Mac. balt.*, 1 *Mya aren.* Alive: 3 *Mac. balt.*, 1 *Littorina litt.*

At 0.65 m. depth, c. 20 m. from the shore, were seen only 1—2 dead *Nereis* per sq. metre. B.S. 0.1 sq. metre: *Zostera.* Decayed: 8 *Cardium ed.* Alive: 6 small *Mya aren.*

At 1 m. depth: No dead *Nereis* on the surface of the sand. B.S. 0.1 sq. metre: Decayed: 10 *Mytilus ed.*, 1 *Cardium ed.* Alive: 8 *Mya aren.*, 8 *Mac. balt.*, all small.

At 1.6 m. depth: a number of dead *Mytilus edulis* with decayed soft parts, presumably fallen down from the piles of the jetty. 2 living *Littorina litt.*

On the same day, March 26th, an area of 0.15 sq. metres was dug up on the sandbank mentioned above. Here were found 3 decayed *Arenicola marina*, 1 decayed *Scrobicularia plana*, 6 *Nereis diversicolor*, which were still alive but had lost a greater or less part of the hinder end, and 3 living *Macoma baltica.* In the shallow water (depth less than 1 metre) close at hand were found a number of *Mya arenaria*, 3—6 cm. in length, lying on the sand. Of 37 specimens 24 were dead and decayed; the rest were still alive but were very feeble; the adductor muscle was evidently paralysed and only the siphons reacted to the touch by contracting. Also a number of dead *Arenicola marina* lay on the sand and only quite a few heaps of excrement were found within the 1 metre line.

April 18th, 1929. The sandbank at Avernakke. Low water. Large dead *Mya arenaria* shells are seen in several places half out of the sand (Fig. 1); the animals have died in the winter, for the brown cuticle of the siphons still clings to the shells of several individuals. All the *Mytilus edulis* on the sandbank have been killed by the cold (Fig. 2); the remains of the adductor muscle are still seen in the shells. Upon digging up an area of 1 sq. metre the following animals were found:

Dead with decayed soft parts:
- 17 large *Mya arenaria*,
- 2 *Macoma baltica*,
- 2 *Scrobicularia plana*,
- 1 *Arenicola marina* (lay deep in the sand).

Alive:
- 1 large *Mya arenaria*,
- 4 *Macoma baltica*,
- 12 *Nereis diversicolor* (many of these lacked the hinder end).

Since at this spot, according to investigations carried out before the ice period, there were on an average about 20 sand-worms per sq. metre of bottom (see also observation for February 21st above) the mortality among *Arenicola marina* can now be put at about 95 %.

Fig. 1. Sandbank in Nyborg Fjord after the end of the ice period. Low water. The hinder end of numerous dead *Mya arenaria* are visible protruding from the sand. All the large white shells in the photograph are of dead *Mya arenaria*; the greater number have been killed during the winter. In the middle distance is seen a metre measure.

Photographed April 18th 1929 by H. Blegvad.

Fig. 2. Part of the sandbank in Fig. 1, showing *Zostera* and *Fucus*, as also numbers of *Mytilus edulis*, all killed by the winter cold. The shells are visible as black specks on the top of the masses of seaweed.

Photographed April 18th 1929 by H. Blegvad.

According to the above figures, the mortality among *Mya arenaria* was 94 %; but in other places in the vicinity it varied between 100 % and 80 % so that on an average it may be put at c. 90 %. Of the *Mya* mentioned in the observation for March 26th above, which lay free on the sand with the adductor muscle paralysed, only quite a few were now found; most of them had apparently fallen an easy prey to crabs and starfish.

Of decayed *Nereis diversicolor* not another trace was found. Since at this spot previous to the ice period there were about 40 *Nereis* to the sq. metre of bottom the mortality remains unchanged at 70 %.

As regards *Macoma baltica*, both the figures quoted above and other samples taken in the vicinity point to a mortality of about 33 %; it has thus risen slightly since February 21st, but is still surprisingly low.

In the case of *Mytilus*, *Cardium*, and *Scrobicularia*, the mortality must be taken, according to the figures available, to approximate very closely to 100 % on this sandbank. The same applies to the *Littorina littorea* which have remained here, but the bulk of these animals have probably — together with the Gastropods of the *Zostera* region — some time before the commencement of the ice period moved to the soft bottom in the plant region in somewhat deeper water; only comparatively few *Littorina* have namely been found in the area under investigation during the ice period and immediately after it.

July 15th, 1929. The sandbank at Avernakke. Low water. 1 sq. metre dug up.

	Alive	Died in the winter
Arenicola marina	1, c. 5 cm in length	..
Nereis diversicolor	27, - 3—6 cm	..
Mya arenaria	10, - $2^1/_2$—$3^1/_2$ cm	10, c. 3—$6^1/_2$ cm
Scrobicularia plana	..	7, - $3^1/_2$ cm
Macoma baltica	21, - $^1/_2$—1 cm	13, - $^1/_2$—1 cm
Cardium edule	16, - $^1/_2$—1 cm	11, - $^1/_2$—$1^1/_2$ cm
Littorina littorea	3	8

This investigation was undertaken in order to form some estimate as to how far the sandbank at the time in question had begun again to be populated. As will be seen, this does not yet seem to have taken place in the case of *Arenicola* or *Scrobicularia* whereas the large number of *Nereis* indicates that these animals have begun to immigrate. In addition the many living *Mya* and *Cardium* point in the same direction; it is characteristic that the dead specimens are all comparatively large, whilst the live ones are for the most part smaller although these are in general more liable to be killed by the cold. The explanation can only be that the small individuals have immigrated from somewhat deeper water; it is possible however that some of the smallest *Cardium* belonged to the 1929 spat; of the remaining species no 1929

spat was found. The large number of *Macoma baltica* is surprising, but as the relation between the living and dead individuals is about the same as it was just after the ice period, namely a mortality of c. 38 %, it does not appear that any new immigration has occurred. That live *Littorina littorea* have immigrated is no more than was to be expected.

It is very striking that in the course of these investigations no *Aricia armiger* whatever have been found, although this species was extremely common here before the ice period. It may be taken for granted that this small species of worm, which inhabits the top layer of sand and is thus especially exposed to the effects of cold, has been completely exterminated on the sandbank by the cold.

II. Bagenkop (Langeland).

Investigations were carried out here in the shallow water along the shore on April 11th, 1929. Small *Mytilus edulis* were observed to have died en masse along the edge of the shore; they lay washed up in the bank of seaweed on the beach, many still with the remains of the adductor muscle in the shells. A few dead and decayed *Mya arenaria* lay on the edge of the shore and a single *Nereis diversicolor* was seen on the sand still alive but with its hinder end decayed away; it was evident however from the fresh heaps of *Nereis* excrements visible here and there on the sand that they were not all dead or dying. But apart from *Mytilus* no evidence was found to indicate any wholesale destruction of the animals of the littoral fauna; it may be mentioned that the bottom in the shallow water was very stony and gravelly and has therefore certainly not harboured any abundant fauna. The ice was fast-ice here for about 2 months, from the end of January till the end of March 1929.

III. Middelfart.

According to Speerschneider (loc. cit.), ice began to form on February 1st, 1929 both in the Belt and in the harbour; but whereas the harbour was covered with thick fast-ice from February 7th until the end of the month, the Belt was free from ice throughout nearly the entire period; in March the harbour was reported free from ice already on the 3rd, and in the Belt there was only drift-ice from March 3rd until the 10th, being afterwards free from ice.

In accord with the comparatively small amount of ice only faint traces of the effects of the ice on the littoral fauna were found at the investigation of conditions on the shore at Middelfart on April 8th, 1929. Here, as everywhere, it was particularly *Mytilus edulis* which had suffered; numerous fresh empty shells lay washed up along the beach. Also a number of *Cardium edule* had died during the winter, but nowhere were any traces of dead worms to be seen; on the contrary, at Teglgaard in very shallow water, $^1/_2$—$^1/_3$ m. in depth, were noticed a number of heaps of excrement from *Arenicola* and *Nereis*.

IV. Koldby Kaas (Samsø).

Pack-ice was already present here on February 4th, 1929, and from February 7th there was heavy fast-ice right up till March 20th; from March 27th the water was free from ice. The greatest thickness of ice is given as 60 cm. (Speerschneider).

On April 4th, 1929, an investigation was carried out along the coast by Koldby Kaas harbour at low tide. Surprisingly few animals were found killed by the cold and ice. A few large *Cardium edule* recently dead were seen as also just a few *Mytilus edulis*. But many more large living *Mytilus* were found high up the beach, and in particular there were swarms of large *Littorina littorea*. According to the statements of local fishermen, vast masses of seaweed (especially different *Fucus* species) were washed up here, just before the ice formed, and evidently protected the littoral fauna from the effects of the cold.

V. Anholt. North-West Reef.

In the sea beyond Anholt harbour, according to a report kindly furnished by Commander Speerschneider, there was scattered drift ice on February 3rd, 1929, heavy drift-ice from February 7th, and drifting heavy ice floes from February 11th. The heavy drift-ice persisted until March 17th, upon which date scattered drift-ice was reported; on March 21st the water was free from ice.

Fig. 3. The shore at Anholt, North-West Reef. Washed up edging of animals killed by the winter cold. The bulk consists of *Mactra subtruncata* and *Pectinaria koreni*. In the middle distance there is a metre measure.

Photographed by H. Blegvad, May 3rd, 1929.

On May 3rd, 1929, a broad belt, about 2 km. long and $^1/_4$—1 m. wide, of shells and tubes of the following animals was found washed up on the shore at Anholt

North-West Reef: *Mactra subtruncata*, *Pectinaria koreni*, *Macoma baltica*, *Tellina tenuis*, *Mytilus edulis*, *Mya arenaria*, *Cardium edule*, and *Tellina pusilla*, (Fig. 3). The two first species were the most numerous, their numbers running into millions. Most of the shells were still joined together in pairs, and in many of them were still the remains of the soft parts on the inner side; the *Pectinaria* tubes were quite fresh, often completely intact; in short, all the animals gave the impression of having died more or less simultaneously and comparatively recently. There can therefore be no doubt that a wholesale destruction of the animals species mentioned had taken place here, caused by the cold and the violent screwings of the ice, which according to the statements of the local fishermen had taken place on the North-West Reef.

Upon visiting the same locality on August 6th, 1929, only a few fragments were found to be left of the brittle *Pectinaria* tubes. Most of the shells of the thin-shelled *Tellina*, *Macoma*, and *Mactra* were ground to a quite fine shell gravel, which like a white edging bordered the surf zone or lay in small patches spread over the lower beach. Only the large *Cardium edule* and *Mya arenaria* were found still intact in the shell gravel.

VI. Als Odde (Entrance to Mariager Fjord).

According to a report kindly furnished by Commander Speerschneider, there was thin fast-ice here already from January 12th, 1929; on January 16th thick fast-ice was reported, on March 1st packed ice, which changed to heavy drift-ice on March 14th; on March 20th the water was free from ice. The greatest thickness of ice was found by measurement to be 30 cm.

On May 8th, 1929, the water being unusually low (c. $^1/_3$ m. below mean water level) conditions were investigated on the extensive sandbanks in the entrance to the Fjord. Already as in calm weather we were passing the sandflats lying dry on both sides of the channel, a smell of decay was perceptible which later proved to emanate from innumerable decaying *Cardium edule* and *Mytilus edulis* which lay on the surface of the sand. On the other hand, there was no sign of any wholesale destruction of the other littoral animals. Millions of heaps of excrement from *Arenicola marina* were found close together over the whole area; by digging in the sand many living *Macoma baltica* were found, in addition to sand-worms and *Mya arenaria*, but a few empty shells with the remains of the soft parts lay on the surface of the sand. *Littorina littorea*, *Littorina tenebrosa*, and *Hydrobia* were crawling about in large numbers, both on the tracts left dry and on those under water. At long intervals a few larger *Mya arenaria*, recently dead, were seen. On the other hand, comparatively few *Nereis diversicolor* were found by digging; it is reasonable to suppose that these animals had fallen victims in large numbers to the cold, but that all trace of them had been washed away later, as was the case at Nyborg. At a depth of 10 cm. below the surface of the sand was found a thick layer of shells of dead mussels of all sizes (especially *Cardium edule*, *Macoma baltica*, and *Mya arenaria*); the death of these animals was probably due in great measure to previous ice winters.

Summary.

It has been shown in the foregoing that everywhere where investigations have been carried out it has been possible to establish the effects of the long frost in the winter of 1928—29 on the bottom animals of the littoral fauna in the inner Danish waters. The deadly effects of the cold have not however been uniform for all species within the same locality, some species having shown greater powers of resistance than others. Similarly, local conditions have brought about certain divergencies with respect to the extent of mortality.

As was to be expected, mortality has been greatest among the species which are most liable to be frozen stiff; this applies first and foremost to *Mytilus edulis*, partly because it lives in places where it is most liable to be frozen in the ice and partly because it cannot avoid the ice by burying itself or by moving to deeper water. It is well-known that many animals can support being frozen stiff for a short period (see for instance with reference to *Mytilus* R. W. Dodgson: Report on Mussel Purification. Min. Agr. & Fisheries. Fishery Investigations. Series II, Vol. X, No. 1. 1928, p. 195), and this is undoubtedly the reason that I do not remember in previous winters having seen that the animals of the littoral fauna have died *en masse* to any pronounced extent over large areas, but a continuous ice period, lasting for months, such as we have had during the winter of 1928—29 has killed millions of individuals. The mortality among *Mytilus edulis* at depths from 0—1 m. approximated in most places very closely to 100 %.

Also *Cardium edule*, which has quite short siphons and is therefore incapable of burying itself far down in the bottom, has been found killed in large numbers, especially in places which have lain dry at low water; on a sandbank at Nyborg the mortality among this species was found to be about 80 %.

Those Lamellibranchs which have long siphons and therefore live deeper down in the sand are less subject to being frozen stiff. Nevertheless the mortality amongst *Mya arenaria* has proved everywhere to be fairly great; it has been shown by digging during the ice period that in places which are left dry at low water the top layer of the bottom freezes into a solid mass, causing the Lamellibranchs to draw their siphons deeper down; they then either suffer from lack of oxygen or the muscles may relax, especially the adductor muscle, presumably owing to ice crystals forming within them; this again causes a paralysis of the muscles so that in most cases sooner or later death ensues. On a sandbank in Nyborg Fjord the mortality among *Mya arenaria* after the end of the ice period was about 80 %. Of *Scrobicularia plana* were found only dead individuals, whereas on the other hand *Macoma baltica* seems to have greater powers of resistance to the effects of cold; the mortality in the above-mentioned locality was shown to be about 33 %.

As regards Polychæta, a high mortality was found especially among the smaller forms, e. g. *Nereis diversicolor*; in places left dry at low water were found numbers of these animals frozen stiff in the top layer of the bottom; others had sought refuge in the deeper layers. The mortality in the above-mentioned place in Nyborg Fjord

was about 70 %; after the frost period had come to an end whole layers of dead *Nereis* were found in certain spots lying upon the bottom near the edge of the shore. It is peculiar that many of the *Nereis* which survived the ice period were found with the hinder end decayed away, evidently a result of the cold. The still smaller form *Aricia armiger* seems to have perished completely in the shallowest water in Nyborg Fjord; in any case no trace of it was found here after the end of the ice period. The larger forms such as *Arenicola marina* in exposed places bury themselves deep in the bottom; in Nyborg Fjord this species was found during the ice period at depths right down to 40—50 cm. below the surface of the bottom, and the *Arenicola* which were found in the layers above were for the most part dead or dying. In the locality, mentioned on several occasions, in Nyborg Fjord the mortality at the end of the ice period was as high as c. 95 %, but in other places which had evidently not been so exposed to the cold, e. g. the large sand-flats at the entrance to Mariager Fjord, it was much lower.

As regards Gastropods, the *Littorina littorea* which were found in the shallowest water, where they were exposed to the danger of being frozen in the ice at low tide, were all dead; they were however so few in number that the bulk of them — just as the Gastropod species of the *Zostera* region — may be assumed to have moved out, somewhat prior to the commencement of the ice period, to the plant region in such deep water that the temperature of the bottom remains above freezing point. C. G. Joh. Petersen (Report of the Dan. Biol. St. III, 1892, p. 31) has shown that the temperature in Kolding Fjord in abt. two fathoms of water, 3—4 ft. down in the mud, was c. 7° C. throughout the entire winter, although the temperature of the water was about 0° C. Both shrimps and crabs find their way thither in winter.

Local conditions, such as a steeply shelving beach and a strong current (Middelfart), which prevent the littoral zone from becoming covered with ice for longer periods, or the presence of large masses of seaweed which protect the animals against the effects of the cold (Koldby Kaas on Samsø) may considerably reduce the mortality. On the other hand, violent screwings of the ice can extend the death-dealing effects of the ice to depths which they would not otherwise reach; the finding of millions of *Pectinaria koreni*, killed by the ice, at Anholt North-West Reef thus indicates that the violent screwings of the ice which occurred here have extended right down to depths of more than 2—3 m., since *Pectinaria* seldom occur in shallower water.

I have previously shown (Report of Biol. St. XXXI, 1925, pp. 35—36 & 47) that in the spring individuals of the species *Corbula gibba* (in the Limfjord) and *Mactra subtruncata* (in the Kattegat) are found in millions in water up to 5—6 m. in depth with their shells tightly closed, but with the soft parts decayed, and that this is presumably due to severe winters. It is even a fact that the latter species may be regarded in our inner waters as living for the space of one year only, since the bulk of the individuals die regularly during the winter, whereas in other places, e. g. in the North Sea, the species lives for many years. Also the oyster (*Ostrea edulis*) succumbs extensively to the cold in severe winters, even in comparatively deep

water. R. Spärck (Report of Dan. Biol. St., XXXIII, 1927, pp. 61, 62) ascribes this to the water being excessively cooled, whereby ice crystals are formed in the adductor muscle of the oysters, since the mortality was especially marked in localities where the waters were free from ice during the frost period. Something of the same kind occurs also no doubt in the case of *Corbula gibba* and *Mactra subtruncata*; it should be noticed that all three species are pronounced boreal forms.

Severe winters thus not only exert a direct death-dealing influence on bottom animals in the shallow water along the coast through large masses of ice accumulating there, but their effects can also reach down to depths of 5—6 m. and more when the sea-water close to the bottom is excessively cooled.

The investigations described in the foregoing have shown that the bottom animals of the littoral fauna are on the whole particularly exposed to the danger of being killed in ice winters in the coastal belt from 0 m. to c. 1 metre's depth, and especially in places which are liable to be left dry at low water. Certain species, such as *Mytilus edulis*, are frozen in the ice, others (*Aricia armiger*, *Nereis diversicolor*, *Cardium edule*) are liable to be frozen stiff at low tide; others again (*Mya arenaria*, *Macoma baltica*, *Arenicola marina*) probably die from lack of oxygen. In the edging of washed up mollusc shells which every spring borders the surf zone along our coasts can be found individuals of all ages; there can hardly be any doubt that the bulk of these animals is composed of the millions of bottom animals of the littoral fauna which fall victims every year to the winter cold.

III.

Mortality among Porpoises, Fish, and the larger Crustaceans in the Waters around Denmark in severe Winters.

By

A. C. JOHANSEN

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I. Introduction.

In every severe winter when certain of the Danish waters are covered with ice, there are observed here and there a striking number of dead fish and other dead animals. They are found partly frozen in the ice, partly drifting in the water amongst the brash, and partly cast up on the shores. The dead animals are often first seen during fishing operations when they are brought up from the sea-bottom by fishing implements of various kinds after the ice has disappeared.

It is obvious that an investigation into the question of whether there are many dead animals on the sea-bottom, during a period when the waters are covered with ice, must be very incomplete. But even in such periods fishing is carried on in the fjords and coastal waters with several kinds of implements, first and foremost in the form of catching eels with spears from the surface of the ice (Eel-spearing). In addition to this, fishing is carried on here and there with weels and gill nets, which are let down through openings in the ice. In a few places seines are also dragged under the ice.

As it is impossible from a small number of observations to obtain a collective impression of the harmful effects of severe ice-winters, I have sought to gather comprehensive information as to the occurrence of dead fish and other dead animals from all the Danish waters in the winter of 1928—29, in which there was an unusually protracted and severe period of cold.

The information regarding the dead marine animals in Danish waters, which is to be discussed here, has been obtained from the following sources:

1) Observations from the Danish Biological Station and the Danish Commission for the Exploration of the Sea.
2) Observations made by the staff of the Fishery Patrol collected by Mr. A. Jørgensen and Mr. Trolle Thomsen, Fishery Superintendents.
3) Observations made by several well-known fishermen and men interested in fishery from various parts of the country.

I wish to thank all those who have placed at my disposal their observations as to the occurrence of dead marine animals in ice-winters.

II. Ice Conditions in the Winter of 1928—29 and in Previous Winters in the Waters around Denmark.

The winter of 1928—29 was unusually severe and was moreover noticeable in that there was only one continuous ice-period, which lasted almost three months in the inner Danish waters, from the middle of January until the beginning of April.

In Table 1 is presented a comparison, derived from Captain Speerschneider's paper "The State of the Ice in the Danish Waters during the Winter of 1928—1929"[1]), between the different winters, as regards ice conditions and temperature in Danish waters for the period 1906—29. The last column in the Table refers to the following stations: Fanø (Nordby), the Skaw (Lighthouse), Hesselø (Lighthouse), Bogø (School of Navigation), Copenhagen (Trekroner), and Hammershus (Sandvig). The "total amount of cold" given in the Table is arrived at by multiplying the number of days by the mean temperature of the frost period.

Table 1. Comparison between the different winters as regards ice and temperature conditions in Danish waters.

(Figures furnished by Captain Speerschneider.)

	No. of days when ice was present			Mean figures for "total amount of cold"
	Open waters	Enclosed waters	All stations	
1906—07	*6,6*	*57,9*	*30,3*	121,1
1907—08	0,2	32,2	10,1	65,8
1908—09	*18,6*	*66,3*	*38,8*	151,6
1909—10	0,1	20,7	5,7	37,9
1910—11	0,0	5,6	2,4	23,9
1911—12	*17,7*	*52,9*	*31,5*	128,6
1912—13	0,3	19,1	7,4	31,9
1913—14	0,1	16,6	6,0	49,2
1914—15	0,0	19,3	6,1	66,3
1915—16	0,1	22,1	7,3	68,2
1916—17	*21,4*	*78,5*	*44,9*	169,5
1917—18	1,2	48,1	15,3	79,4
1918—19	0,7	31,1	11,6	65,2
1919—20	0,0	41,0	11,9	64,3
1920—21	0,0	4,1	0,9	11,3
1921—22	*30,6*	*52,9*	*39,4*	165,4
1922—23	2,5	23,8	11,0	57,5
1923—24	*40,3*	*111,3*	*68,0*	238,8
1924—25	0,0	2,0	0,5	27,9
1925—26	0,4	53,2	16,9	94,4
1926—27	0,0	4,3	1,7	21,8
1927—28	*7,0*	*57,5*	*25,4*	110,3
1928—29	*48,4*	*87,1*	*62,3*	266,7

In terms of the "sum of cold" the winter of 1928—29 was thus the most severe within the period in question. In terms of the number of days when the waters were covered with ice the winter of 1923—24 was the most severe, the winter of 1928—29

[1]) Special publication of the Nautical-Meteorological Annual 1929.

Fig. 1. Ice conditions in the waters around Denmark on March 1st, 1929. (Data supplied by Captain Speerschneider.)

taking second place. Furthermore, the ice-periods in the following winters were of comparatively long duration: 1906—07, 1908—09, 1911—12, 1916—17, 1921—22, and 1927—28.

The position as regards the ice in the waters around Denmark was on Feb. 1st, 1929, according to the data supplied by Captain Speerschneider, as follows:

The Danish fjords and inlets were covered with fast-ice. It also extended over the inner portion of Køge Bay, Faxe Bay, and the Smaaland Sea. In the greater part of the Belt Sea there was thin fast-ice, drift-ice, or bay-ice. The main part of the Kattegat was free from ice, as were also the North Sea, Skagerak, and the waters around Bornholm.

During the month of February the Kattegat, Sound, Belt Sea, and the western part of the Baltic as far as Bornholm froze more and more, being now covered for the most part chiefly with fast-ice and heavy pack-ice. The eastern part of the Skagerak began to freeze and thin fast-ice began to form in the eastern part of the North Sea off the west coast of Jutland.

In Fig. 1 is given a survey, derived from data furnished by Captain Speerschneider, of the ice conditions in the waters around Denmark on March 1st, 1929, when the extent of the ice was at its maximum. In the waters E. of Bornholm the ice extended for a short period further to the east than is shown on the map. (For the advance of the ice towards the east in the Baltic see Fig. 2.)

Shortly after March 1st the areas covered by the ice began to diminish. The ice in the North Sea and Skagerak near the coast of Denmark had already vanished in the first week of March, and by the middle of March the greater part of the western Kattegat was free from ice. In the western part of the Baltic between Sealand-Falster and Bornholm the ice remained for a comparatively long time, and even on March 23rd there was still drift-ice off the western coast of Bornholm.

In the fjords and inlets the ice began to disappear here and there at the end of March, but in most places it remained until the beginning of April.

III. Observations on the Occurrence of dead Porpoises, Fish, and the larger Crustaceans in the Winter of 1928—29 and Previous Winters in the Waters around Denmark.

A. The North Sea.

No dead plaice, cod or haddock were observed in the fishing implements during fishing operations carried out from Esbjerg and the smaller fishing villages on the west coast of Jutland in Feb.—April, 1929.

Information has been received from several different quarters to the effect that a number of dead soles were taken up in the south-eastern and eastern parts of the North Sea at about 25—50 metres depth by Danish cutters using the Danish seine, in the last half of March and throughout the whole of April 1929.

Fig. 2. Map of the inner Danish waters and the western part of the Baltic. In the latter waters the gradual advance of the ice towards the east in February — March, 1929, is shown, the data being furnished by Captain Speerschneider. Neither fast-ice nor pack-ice extended at any time beyond the north-eastern part of the Bornholm Deep, but flake-ice was observed there on March 21st, 1929.

The following items are taken from the information received:

"In the last half of March and throughout the whole of April a number of dead soles were taken up in the south-eastern part of the North Sea, at depths of 15—20 fathoms by cutters from Esbjerg using the Danish seine. When fishing was carried on at depths of more than 20 fathoms all the soles in the catches were alive." (See list of our informants, p. 95, No. 51.)

"The cutters "Pax" and "Eline" from Lemvig, fishing with the Danish seine 75—80 nautical miles W. by S. of Thyborøn took up here at c. 40—50 metres' depth many dead or nearly dead soles between the middle of March and the middle of April 1929. The fishermen assumed that death had been caused by cold" (85).

We also possess evidence as to a considerable mortality amongst certain crustaceans in the eastern part of the North Sea in the winter of 1928—29. Mr. Buus, harbour official at Thyborøn, informs us that several fishermen from Thyborøn took up a striking number of dead crab-fish (*Cancer pagurus*) during fishing operations near the west coast of Jutland at depths of under 20 metres in the early spring of 1929.

After the ice had disappeared in the spring of 1929 a number of crabs drifted ashore on the west coast of Jutland off Nymindestrøm and Ringkøbing Fjord. Bloch (5) reports that one or two kilometres S. of Nymindegab on a short stretch of coast there were 2—3 cart-loads of dead crabs, almost all livid svimming-crabs (*Portunus holsatus*), a few crab-fish, and one or two sand-crabs (*Hyas*).

One might have assumed that these animals had been cast ashore during a violent westerly storm without having been already killed by the cold, but the winds in March and April 1929 were comparatively gentle along the west coast of Jutland. On only a single day in April did the wind velocity reach 12 metres per second.

B. The Baltic.

From information received from several quarters it is clear that in Bornholm Deep towards the end of the winter 1928—29 there was a very great mortality amongst porpoises (*Phocæna communis*), whereas few dead fish seem to have been observed.

The following items are taken from the information received:

"In the waters around Bornholm a number of dead porpoises were fished up with trawls after the ice-period in the spring of 1929. I have heard nothing of any dead fish at Bornholm and Christiansø except for a few eels which may be screwed up to the surface by the ice" (49).

"After the ice had disappeared from Bornholm Deep in the spring of 1929 about 40 fishing vessels began to fish with otter trawl for plaice and flounders. The vessels were of 12—20 tons gross, and the length of the ground-rope of the trawls

employed varied from c. 50—80 feet. No dead fish were observed, but a number of dead porpoises were taken up in an area situated c. 22—24 nautical miles E. of Nexø, and where the depth was c. 90—100 metres. The cutter "Chr. Møller" on one day took 14 porpoises in the trawl, and in all several hundred were taken by all the vessels together in the course of 6 weeks.

The first porpoises taken up were quite fresh, but they became more and more soft and decomposed and finally went to pieces when they were taken up.

A few porpoises were taken up 10—12 nautical miles from NE. to SE. of Nexø at depths of 60—80 metres."

To an enquiry as to whether there were seals amongst the many porpoises, our informant Mr. Hans Møller, of Aarsdale, replied that there were not. "Seals are much too clever to let themselves be taken unawares, they go up on to the ice when it begins to be too uncomfortable for them."

"After the ice-period in 1924 several dead porpoises were taken with the Danish seine in the Baltic, chiefly in the Kadet Channel" (20).

No particularly great mortality among the fish was observed in the winter of 1928—29 off the Baltic coasts of Sealand, Møen, and Falster. After the ice had disappeared in the winter of 1921—22, an unusually great number of dead eels drifted ashore in Køge Bay, and many half-dead eels were seen lying at the water's edge" (59).

C. The Waters between the North Sea and the Baltic.

1. Skagerak.

Neither in the open Skagerak nor along the Danish shores of the Skagerak were any observations made which might lead one to suppose that the mortality amongst fish and other marine animals was greater than normal in the winter of 1928—29.

Alf Dannevig mentions[1]) that in the district round Arendal during a very cold period in 1922 large numbers of dead fish were observed of several different species, such as the pollack (*Gadus pollachius*), the coal-fish (*Gadus virens*), the cod (*Gadus callarias*), the black goby (*Gobius niger*), and the gold sinny (*Ctenolabrus rupestris*). A number of the fish were frozen fast in the ice.

During a cold period in March 1923 there was in the same district a similarly great mortality amongst several species of fish, such as the cod, the sea scorpion, the gold sinny, and the lesser fork-beard (*Raniceps raninus*).

[1]) Alf Dannevig in Aarsberetning vedk. Norges Fiskerier for 1924. Bergen 1926, pp. 187—189.

2. Kattegat.

All the information in our possession received from fishermen, who have fished with the Danish seine and the otter seine in the Kattegat outside the 20 metre line after the ice had disappeared in the spring of 1929, is to the effect that dead fish have not been taken up in the seines in appreciable quantities.

On the other hand we have been informed that after the disappearance of the ice in the spring of 1929 a number of dead cod, c. 40—80 cm. in length, were taken up during fishing operations with the Danish seine in Aalbæk Bay near Strandby, and that a number of dead plaice, c. 11—19 cm. in length, drifted ashore.

It has also been observed in other severe winters that dead plaice have drifted up on to the shores of Aalbæk Bay, but there have never been seen so many dead fish before as in this last winter (39).

Along the shores of the northern Kattegat a number of small turbot of about 12 cm. average length drifted ashore after the ice had disappeared in the spring of 1929 (23).

From several quarters we have received information to the effect that many cod caught in weels along the shores of the Kattegat were found dead when the weels were inspected. Of the facts communicated to us the following may be mentioned here:

"It has been observed this winter (1928—29) as in former winters that when a hard frost sets in with a strong easterly breeze, the cod die in the weels along the shores of the Kattegat when the weels do not stand in a depth of water of at least 5 metres" (77).

3. Belt Sea.

Fishing operations with a fine-meshed trawl (Eeltog) were carried out from the Danish Biological Station's steamer "Japetus Steenstrup" immediately after the ice had disappeared in April 1929 in several different localities in the Belt Sea, especially in Kerteminde Bay and Baaring Vig, but no dead fish or other large marine animals were observed in any of these places.

From the cutter "Ebba" which accompanied the "Japetus Steenstrup", fishing operations were carried out with the Danish seine in April 1929 at 7 different localities in the Belt Sea, but no dead animals were taken up from the sea-bottom.

The places where the fishing operations were carried out were the following:

(1) Kerteminde Bay; (2) Sælvig Bay, Samsø; (3) Between Endelave and Koldby, Samsø; (4) E. of Brandsø, Lille Belt; (5) At Søby, Ærø; (6) Lunke Bay, S. of Funen; (7) Great Belt off Lundeborg.

Most of the reports from other fishermen who have fished with the otter seine or the Danish seine in the Belt Sea immediately after the disappearance of the ice

in the spring of 1929 are also to the effect that no dead fish have been taken up from the sea-bottom in any appreciable numbers, but there are, however, a few reports which assert that at certain spots in Lille Belt and the waters SW. of Ærø considerable numbers of dead fish have been taken up in the fishing gears. These reports follow:

"Close to Vodrup Flak, SW. of Ærø, several dead cod were taken up with the Danish seine from a depth of 26 metres, shortly after the ice had disappeared in the spring of 1929" (1. 63).

"Very shortly after the ice had disappeared in the spring of 1929 the vessel E. 266 (now A.A. 6) started fishing operations with the Danish seine in the waters of the east of Als. On the fishing ground 2 nautical miles SE. of Mommark, with hardly any exceptions only dead fish, especially cod, haddock, plaice, and flounders were taken up on the first fishing day from a depth of 36 metres. The fish had begun to decompose and were unfit for marketing. Far the greater part were fairly large fish. The cod weighed 2—3 kg. each, and the haddock 1—1,5 kg. — Also on the following days many dead fish were taken up" (63).

"In Lille Belt between Sønderballe Hoved and Barsø several dead cod, haddock, plaice and flounders were taken up with the Danish seine from a depth of 20 metres, as also a single eel, shortly after the ice had disappeared in the spring of 1929" (1. 63).

From the information received as to the dead animals which have drifted up on to the shores of the Belt Sea the following items are quoted here:

"At Fynshav on Als many dead eels drifted ashore in the winter of 1928—29" (15).

"After the first severe period of frost and the north-easterly storm on Jan. 16th—17th, 1929, many silver-eels drifted ashore along the east coast of Als between Fynshav and Fleimose. About 250—300 kg. of these eels were collected, a number of them being still alive. After some days had elapsed, the eels which lay and drifted in the brash became yellowish in appearance and the islanders therefore considered that they were unfit for human consumption" (33).

"After the ice-period in the spring of 1929 two dead porpoises drifted ashore at Aarø" (100).

"A single dead porpoise drifted up on to Enø Beach after the ice had disappeared in the spring of 1929" (36).

We have received the following information as to the occurrence of dead fish in the narrowest part of Lille Belt in severe winters:

"After the ice-periods, dead and blind eels may be collected along the shores of Lille Belt. They appear, however, in the largest quantities in those years when the Belt does not freeze completely, and when the drift-ice is repeatedly forced on to the shore. In 1917, for instance, about 500 kg. of dead or feeble eels were collected at Fredericia and Strib" (94).

"During an easterly storm in the winter of 1925—26 with the temperature below freezing point, a great number of haddock were cast up on to the shores of Lille Belt" (64).

"Some years ago, when there were more haddock here than there are at the present day, several hundred pounds of haddock were taken during a hard frost floating on the water (off Middelfart) with a strong north-going current" (70).

In the winter of 1921—22 dead cod were observed, off Snoghøj in Lille Belt, which were frozen in the ice. The fisherman Mr. Laurs Rungborg helped to cut several of these cod out of the ice and they were found to be in good preservation. When the ice broke up, many dead cod drifted up on to the shores of Lille Belt (96).

Amongst the cod caught in weels in the open parts of the Belt Sea there has evidently been a considerable mortality. Two reports to that effect follow herewith:

"I had 100 cod weels standing out off Sejrø for the first fortnight of this last ice-winter (1928—29), and when I came to take them up all the large cod weighing more than 2 kg. were dead, whereas all the small ones were alive. The weels stood in c. 7—9 metres of water" (76).

"Last winter (1928—29) during the ice-period, I had 20 cod weels standing on a sea-weed bottom in 6—9 metres of water off Mols Hoved in Aarhus Bay. In the middle of March the ice began to break up and drift about the Bay. At the same time I inspected the weels and found in them c. 100 kg. of living and c. 200 kg. of dead cod. The weels had stood unattended for about 8 days before the ice came" (96).

4. The Sound.

Fishing experiments with a fine-meshed trawl (Eeltog) were carried out from the Danish Biological Station's steamer "Japetus Steenstrup" on April 25th, 1929, to the south of Hveen. No dead fish were found here nor any large dead invertebrates.

Also along the shores of the Sound no dead fish were observed in any appreciable quantity, either during or subsequent to the ice-period in 1929.

Immediately after the ice had disappeared in the spring of 1929, two dead tunnies (*Orcynus thynnus*) drifted ashore at Elsinore at Kronborg Head (105).

"After a severe ice-winter in the Eighteen-seventies a number of dead porpoises drifted up on to the shores of the Sound. They were made use of by being melted down for oil" (91).

D. The Fjords, Coves, and other Inlets.

In the inlets there was considerable mortality among the eels in the winter of 1928—29, and as will be seen from the reports given below it has been established that in certain places also the black goby (*Gobius niger*), the viviparous blenny, the flounder, the cod, the sprat, and several other species have died *en masse*.

1. The Limfjord.

We possess the following reports, amongst others, of the occurrence of dead fish and crustaceans in the Limfjord during the ice-period in Jan.—April 1929 and immediately subsequent to it.

"After the ice had broken up in the spring of 1929, large numbers of sprats, frozen to death, were observed lying on the beach at Viilsund between the ferry and Skyum Hage" (35).

"When the ferry crossed Oddesund during the ice-period in 1929, several dead herring and sprats were observed amongst the ice" (89).

"In Thisted Broad immediately after the ice-period in the spring of 1929, a few fairly large dead cod, weighing up to 5 kg. each, were taken in mussel seines and plaice seines. Moreover, quite small dead fish, 1—$1^1/_2$ inches in length, presumably black gobies (*Gobius niger* L.), were noticed in the plaice seines.

It should be mentioned with reference to previous observations that dead cod have often been seen in Thisted Broad in large quantities. According to the experience of fishermen, cod perish chiefly before the Fjord becomes frozen over, especially when there are snow-storms and a hard frost prevails" (57).

"When the ice broke up in the Fjord in the spring of 1929, a number of dead eels were taken up with nets and the Danish seine, their occurrence being presumably due to the severe winter" (40).

"In the spring of 1929 after the ice had disappeared, a few dead eels drifted ashore from Livø Broad, this being always the case after ice-winters" (53).

"In Skive Fjord gill nets were placed under the ice in several spots during the ice-period in 1929. When the nets were taken up a considerable number of dead viviparous blennies and black gobies (*Gobius niger*) were found enmeshed in them" (102).

"After the ice had disappeared in the spring of 1929 a number of dead lobsters (*Homarus vulgaris*) were found to have drifted on to the shores of Venø Bay along the line Vodstrup—Hjerm—Handbjerg" (89).

"Not a few herring and sprats were found during the ice-period in the winter of 1928—29 in the ice in the waters round Fur. When eels were being speared E. of Fur and N. of Livø dead ones were taken up, and when the ice broke up and the plaice nets were set out up to a score of dead eels were sometimes taken in each net" (6).

"In the winter of 1926, a number of lump-fish (*Cyclopterus lumpus* L.) were taken in the brash in the Limfjord" (85).

"During the ice-period in February 1923, very many cod perished in the Limfjord. Dead cod were observed drifting under the ice, and they were found later washed up on land in considerable quantities" (40).

"During the period of frost in the spring of 1920 numerous sea-trout were killed in Struer Harbour. Whilst the steamship "Limfjorden" was manoeuvring in the harbour, the dead trout came to the surface in fresh condition, choked by the ice in their gills. About 100 were then taken with catcher in the ice in the harbour itself. They were all marketable fish[1])" (89).

2. The Fjords and other Inlets on the North Sea Coast.

Inlets at Graadeep.

"No dead fish have been observed in the inlets at Graadeep during the ice-period in the winter of 1928—29 or after it had ended, whether in weels, seines, or other fishing implements" (104).

In January 1907 the Danish Commission for the Exploration of the Sea had some fishing experiments with prawn-nets carried out in the brook at Maade brick manufactory to the south of Esbjerg, close to where it discharges. The stream was covered with ice but there were openings here and there where the current was flowing.

[1]) i. e. over 37 cm. in total length.

On Jan. 7th, 36 live and 14 dead eels were taken, of the following lengths:

Length in cm.	No. of live eels	No. of dead eels
6.....	1	2
7.....	8	..
8.....	15	10
9.....	10	2
10.....	2	..
Total...	36	14

On Jan. 26th, 2 live flounders and 1 dead were taken, all 4 cm. in length, together with 66 live and 23 dead eels of the following lengths:

Length in cm.	No. of live eels	No. of dead eels
6.....	4	1
7.....	17	4
8.....	26	7
9.....	10	8
10.....	5	1
11.....	3	..
13.....	..	1
14.....	1	..
15.....	..	1
Total...	66	23

None of the eels were elvers. The specimens 6—11 cm. in length had evidently immigrated from the North Sea in the first half of 1906.

Ringkøbing Fjord.

"In the shallows in the southern half of the Fjord the water was for a long time frozen to the bottom. From observations made here during the ice-period and immediately after the ice had broken up, it was discovered that a number of dead eels, viviparous blennies, and flounders lay on the bottom of the Fjord.

In the northern part of the Fjord gill nets were often placed under the ice and the flounders caught in the nets died in many cases with surprising rapidity.

On the whole the fish stock in the Fjord has not suffered any great injury during the severe periods of frost in Jan.—March 1929" (101).

The Nymindestrøm S. of the Dam.

Mr. N. Bloch, Nymindegab, wrote to me in a letter on March 15th, 1929:

"About a fortnight ago the little opening in the ice by the funnel in the dam became covered with ice. When I broke the ice into pieces I saw a thick layer

of eels on the bottom, I should say a good 150—200 kg. Half were dead, and one could pick up the others in one's hands. Most of them were small, less than 30 cm. in length. There were also some dead viviparous blennies and flounders among the eels" (5).

From Mr. E. Høj, fisherman (33) the Danish Biological Station received the following communication regarding the mortality among the fish in the Nymindestrøm during the winter of 1928—29:

"On the bottom of the Nymindestrøm S. of the dam lay many dead eels during the ice-period in 1929. A number of these were taken up with eel-spears, and the flounder nets which had been placed under the ice were full of dead eels when they were taken up. Openings were cut in the ice in many places and these soon became full of eels, of which many were so sluggish that one could pick them up in one's hands."

Nissum Fjord.

"After the ice had broken up in the spring of 1929 a number of dead fish drifted ashore but not in large numbers. The fishermen, however, complained that during the last part of the winter the flounders died as soon as they entered the nets. The flounders were found dead even when the nets only stood for a short time before being inspected" (66).

3. The Fjords and other Inlets on the Kattegat Coasts.

Mariager Fjord.

"Very many dead eels were found in Mariager Fjord after the severe winter of 1928—29. At times even half the eels taken by spearing were dead. No particularly great mortality was observed amongst other fish. In the fishing implements which stood under the ice in shallow water the fish were practically always dead" (58).

Randers Fjord.

"Both in the winter of 1928—29 and in earlier ice-winters many dead eels have been observed in certain places on the fjord-bottom. They are found chiefly in places where there is a hard bottom. The dead eels are taken up partly by spearing and partly (in earlier ice-winters) by the Danish seine" (77).

The Isefjord.

"In the winter of 1928—29 no dead fish were observed in any appreciable numbers in the Isefjord" (20).

"In the most southerly part of the Isefjord, Tempelkrogen, the fishermen who speared eels towards the end of the winter of 1928—29 obtained nothing but dead

eels. In Holbæk Fjord, on the other hand, where it is no deeper no dead eels were taken up" (3).

"In the Fjord at Frederiksværk a few dead eels were observed after the ice had disappeared in the spring of 1929. This always happens after ice-winters" (25).

"After the ice had disappeared in the spring of 1929 a great number of dead sand-skippers (*Gammarus*) were observed in Roskilde Fjord. These animals were presumably dead because the water in the places where they were observed was frozen to the bottom" (72).

"During the period of frost at the beginning of 1924 a great number of cod died in the Isefjord before it became entirely covered with ice. The fish lay and drifted in the brash and some which were in fresh condition were collected by the fishermen" (20).

"In February 1923, the cod died in the Isefjord in large quantities" (H. Blegvad in the Biological Station's Journal, May 17th, 1924).

"During a period of hard frost in January 1912 lasting for some days, large numbers of sprats perished in the Isefjord. They lay partly in the brash, and partly up on the beach. Between Kulhuserenden and Spodsbjerg many boxes of sprats were collected and sold" (20).

"In the winter of 1911—12 a number of sprats and young herring froze to death in the Fjord, where they lay and drifted with the current. Many sprats were brought to land and sold" (90).

"During a hard winter at the beginning of the Nineties, several eels were found in the eastern Channel at Ourø frozen fast in the ice" (81).

Anholt Harbour.

"When the ice broke up in Anholt harbour in the spring of 1929 many dead eels were found there" (83).

4. The Fjords and other Inlets on the Belt Sea Coasts.

a. *The Fjords and other Inlets in the northern part of the Belt Sea.*

From the information received the following items are quoted here:

"At the end of the ice-period in the spring of 1929, weels were standing in 4—4½ fathoms of water at Havnsø in which all the cod were dead. They had been choked by ice crystals in their gills. I have not observed any other dead fish except the double spotted goby (*Gobius ruthensparri*) which have been frozen to death in hundreds, both in the ice and under it. On the other hand, when the ice disappeared

vast numbers of worms of various kinds were to be seen together with sand-skippers (*Gammarus*). They covered the sandy bottom (the reefs close inshore) with a red layer" (106).

"In Norsminde Fjord after the ice had disappeared in the spring of 1929 great numbers of dead eels and some dead trout were found" (65).

"In Horsens Fjord no dead fish have been observed in the winter of 1928—29 beyond a few dead eels. Such dead eels are however picked up by the eel seine every spring" (88).

"At Næraa Strand on the north coast of Funen practically all the eels died during the ice-period in Feb.—March 1929" (55).

"In Korshavn and Pughavn at Fyns Hoved, after the ice had disappeared in the spring of 1929, a large number of dead eels were observed in the shallow water where they had probably been crushed by the ice at low tide" (108).

b. *The Fjords and other Inlets in Lille Belt.*

"When the ice broke up in Kolding Fjord in the spring of 1929, great numbers of dead eels drifted about there along the beach" (12).

"In Gamborg Fjord, after the ice had melted away in the spring of 1929, a number of dead eels were found on the sea-bottom opposite the spot where a stream discharges" (70).

"When cold and stormy weather set in, the cod often die in the weels in Helnæs Bay, but when once the ice has become solid the cod do not die of cold" (43).

"No dead fish were observed after last winter (1928—29) in Genner Fjord and the adjoining waters. In previous years when the ice has formed rapidly, dead eels have been observed in large quantities round the edges of Genner Fjord after the ice has disappeared" (46).

"Dead eels may sometimes be found on the beach at Alssund after an ice-winter, but they are for the most part eels which have been wounded by spears whilst eel-spearing has been in progress on the ice" (99).

"Off Lillehav in Augustenborg Fjord a number of eels, of which many were diseased, were caught during fishing operations in February and at the beginning of March 1929" (15).

c. *The Waters between Funen, Langeland, and Ærø.*

"After the ice had melted away in the spring of 1929, a considerable number of diseased and dead eels were observed in the waters S. of Funen, in Svendborgsund, Lunke Bay, and in amongst the islands. No dead flatfish or cod were taken up from the sea-bottom during fishing operations with the otter seine. A single dead porpoise was observed drifting" (22).

"Fishermen using the eel drift seine observed quite a number of dead eels in the waters between Ærø, Langeland, and Taasinge after the ice had broken up in the spring of 1929. A number of dead eels were also picked up here with spears, especially in the shallow places in the waters around Egholm. It is not rare for the cod to freeze to death in the months Nov.—Dec. when frost sets in suddenly" (67).

"In the waters at Rudkjøbing a few dead eels were observed during the ice-period in Jan.—March 1929 which had presumably entered the shallow water and frozen to death" (21).

d. *Inlets in the Great Belt and the Smaaland Sea.*

Winter 1928—29.

"In Bisserup and Basnæs Fjords a fairly large number of dead eels were observed after the ice had melted away in the spring of 1929, lying on the fjord-bottom in different places" (36).

"After the ice had disappeared in the spring of 1929, there lay on the sea-bottom between Glænø and Sealand a large number of dead fish and other dead animals, such as the flounder, eel, viviparous blenny, sea scorpion, stickleback, black goby (*Gobius niger*), prawns, and shrimps. All the flounders lay on their backs, and all the small animals which live in a fjord had collected everywhere in the Fjord where there were small bare spots devoid of seaweed, and had died there. As much as a bucketful of dead animals might lie on one of these spots, and after the ice had disappeared the water was quite white and milky.

Many dead eels were taken up during spearing operations in the Fjord, but out to sea no dead fish were observed" (69).

"No dead or decaying fish were observed in Karebæk Fjord when the ice broke up in the spring of 1929. On the other hand, it was observed that fishermen who had weels standing under the ice found that numbers of dead prawns came up with the weels when these were taken up at the end of the ice-period" (60).

"In Karebæk Fjord no dead fish were observed during the ice-period in Jan.—April 1929, but on the other hand there were some dead prawns" (13).

"In the winter of 1928—29 practically no dead fish were found in Aunø Fjord. There were however a number of dead eels in the weels which were put out immediately after the ice had disappeared" (79).

"After the ice had disappeared from Nakskov Fjord in the spring of 1929, some dead perch and a few eels were found lying on the fjord-bottom. There were no more dead cod in the cod weels in the Fjord than is normally the case after a period of frost. When frost and stormy weather set in, it happens that some of the cod die in the weels before the ice closes in on them" (44).

Winter 1923—24.

"The eels in Kertinge Nor have suffered greatly from the suffocating effect of the ice in winter, some being dead, others diseased" (C. G. Joh. Petersen in the Biological Station's Journal for May 2nd, 1924).

"In the winter of 1916—17 a large number of black gobies and other bait-fish perished in Aunø Fjord. In places they lay so close together on the fjord-bottom as grains of corn behind the sower. In the same winter I had 10 eel weels standing under the ice, and although they were inspected every day many of the eels died.

Old fishermen inform us that after severe ice-winters many dead perch and pike have drifted ashore" (79).

"In Dybsø Fjord eel weels have often been placed under the ice in winter, and during ice-periods of long duration the eels almost always died in the weels" (79).

"In previous ice-winters our whole stock of cod in Onsevig have often frozen to death in the course of the first few days' hard frost. The same is the case with the cod in the weels on the fishing grounds" (107).

e. *Masnedsund, Grønsund, and Ulvsund.*

"During the ice-period in 1929 no dead eels were observed in Ulvsund, but on the other hand a number of diseased eels.

When the ice broke up in the spring of 1924 dead eels were taken up by the hundred during spearing operations in Ulvsund. As they gradually came to the surface they were snatched up by the sea-gulls" (28).

"During two severe winters, to the best of my belief in 1911—12 and 1916—17, a number of pike and other fish froze to death in the waters S. of Sealand" (1st officer, Mr. L. P. Larsen, Danish Biological Station).

f. *Stege Nor.*

"After the ice had melted away in the spring of 1929, a number of eels and a large quantity of pike fry were observed in Stege Nor, lying dead on the sea-bottom" (56).

g. *The Fjords and other Inlets in the southern part of the Belt Sea.*

In Flensborg Fjord some dead eels were observed during the ice-period in 1929, but on the whole there was not found to be any great mortality among the fish (87).

About $^3/_4$ of a nautical mile E. of Skelde Bro in Sønderborg Bay at a depth of 28 metres, a number of dead cod, haddock, plaice, flounders, and a single trout were taken up during seining operations (from Vessel E. 266) immediately after the ice had disappeared in April 1929 (1, 63, 71).

Immediately after the ice had disappeared in the spring of 1929 the vessel E. 266 attempted to carry out fishing operations with the Danish seine S. of Sønderskov on Als outside Hørup Hav at a depth of about 34 metres. Of dead fish there were taken up here many cod and haddock, some plaice and flounders, 3—4 sea-trout (fairly large), and an eel or two. The fish were soft and had begun to decompose (1, 63, 71).

In the inlets S. of Lolland no dead fish were observed after the ice had disappeared in the spring of 1929, but a number of diseased eels were caught in weels and died after a few days when they had been in the caufs (34).

IV. General Survey of the dead Marine Animals observed in the Winter of 1928—29.

A. Porpoises.

It is clear from the information given in Chapter III that during the ice-period in March—April 1929 a vast number of porpoises (*Phocæna communis* Less.) died in Bornholm Deep, whereas not very many dead porpoises were observed in the Belt Sea. The dead porpoises in Bornholm Deep were found chiefly in an area about 22—24 nautical miles E. of Nexø at about 55°10′ N. Lat., 15°30′ E. Long. at a depth of 90—100 metres. This area seems to have been covered with ice only for some few days in the winter of 1928—29.

The evidence as to the many dead porpoises in Bornholm Deep is surprising, seeing that it is not usual for porpoises to occur very frequently in the waters around Bornholm. One is tempted to assume that the bulk of the dead porpoises in Bornholm Deep came from the Belt Sea, and that the porpoises in the Belt Sea abandoned it in large numbers as it gradually began to freeze over, a large number of them finding their way into the Baltic which became covered with ice later than the Belt Sea (see Fig. 2, p. 69).

The great mortality among the porpoises is obviously due to the fact that the animals cannot breathe when the water is covered with ice which they cannot break through.

B. Fish.

It is clear from the information given in Chapter III that only in areas of slight extent has there been found to be any wholesale destruction among species such as the cod, haddock, plaice, and flounder during the severe winter of 1928—29.

In the southern part of Lille Belt and the adjoining parts of the Belt Sea including Flensborg Fjord, a considerable number of dead cod, haddock, plaice, and flounders were taken up during fishing operations with the Danish seine, but the areas in which these fish occur seem to be of rather small extent.

The localities in which the dead fish have been taken up are situated as follows:

1) SW. of Vodrup Flak at 26 metres' depth
   c. 54°50′18″ N. Lat.; 10°15′30″ E. Long.
2) 2 nautical miles SE. of Mommark Harbour at 36 metres' depth
   c. 54°54′42″ N. Lat.; 10°05′40″ E. Long.
3) $^3/_4$ nautical mile E. of Skelde Bro at 28 metres' depth
   c. 54°52′18″ N. Lat.; 9°46′15″ E. Long.
4) $^3/_4$ nautical mile S. of Sønderskov, Als at 34 metres' depth
   c. 54°52′55″ N. Lat.; 9°51′10″ E. Long.
5) Between Sønderballe Hoved and Barsø at 20 metres' depth
   c. 55°07′30″ N. Lat.; 9°32′10″ E. Long.

The great mortality among the fish in these localities has been in all probability caused by lack of oxygen, or perhaps partially by sulphuretted hydrogen in the water. In the region where the above localities are situated there is frequently a deficiency of oxygen in the lower water layers, even when the waters are not covered with ice.

As will be seen from the analyses submitted below, the bottom water in the above-mentioned region was very deficient in oxygen in the middle of June 1928, and at one station no free oxygen whatever was found in the water.

Investigation of the Oxygen Content in the bottom water in the region around Als, June 12—14th, 1928.

Station	Place, Date, and Depth of bottom	Depth in metres	Oxygen Content in cub. cm. per litre	Percentage of Saturation
920	The Deep outside Aabenraa Fjord	20	5,66	78
	55°3′48″ N. Lat. 9°35′10″ E. Long.	30	4,00	51
	June 12th, 1928. Depth: 34 m.[1])..	33	0,20	3

[1]) At each of the stations 920, 924, and 930 fishing operations with the Eeltog were carried on for 30 minutes. At station 920 no fish were caught, at station 924 3 cod and 38 dabs were caught, and at station 930 18 cod, 8 whiting, 1 long rough dab, and 48 dabs.

Station	Place, Date, and Depth of bottom	Depth in metres	Oxygen Content in cub. cm. per litre	Percentage of Saturation
924	$1^2/_3$ naut. miles NNW. of Norborg Lighthouse, Als. 55°6′10″ N. Lat. 9°40′20″ E. Long. June 12th, 1928. Depth: 29 m.[1])	20	5,38	73
		25	5,35	73
		28	4,34	57
925	Aabenraa Fjord S. of Skær Reef 55°2′18″ N. Lat. 9°30′40″ E. Long. June 12th, 1928. Depth: 30 m....	20	5,22	70
		29	4,30	56
930	$1^1/_2$ naut. miles E. of Mommark harbour. 54°55′50″ N. Lat. 10°5′20″ E. Long. June 13th, 1928. Depth: 36 m.[1])	25	5,98	78
		33	5,08	68
931	$^1/_2$ naut. miles S. of Sønderskov Als 54°52′50″ N. Lat. 9°51′ E. Long. June 14th, 1928. Depth: 34 m....	30	0,29	3
		33	0,00	0

After the ice had disappeared in the spring of 1929, a large number of small dead plaice and turbot drifted up on to the shores of the northern Kattegat.

We possess several reports as to the occurrence of dead soles in the eastern and south-eastern parts of the North Sea at about 25—50 metres' depth during the cold period in March—April 1929. The dead soles were found chiefly NW. of Heligoland in the rectangles L 8, M 7, and M 8, and S. of Lille Fiskerbanke at c. 56°15′ N. Lat. and 6° E. Long. There can scarcely be any doubt that the mortality was due to the low temperature.

The stock of soles in the Kattegat seems not to have suffered particularly from the severe period of cold.

The species of fish which has suffered most from the cold period has evidently been the eel, which occurs chiefly in fjords and other inlets. But the mortality among this species does not seem in any place to have been catastrophic for the stock as a whole. Some of the eels were evidently killed by the severe cold in the water, and others were suffocated under the ice on account of the deficiency in oxygen. A large number of eels become feeble and sluggish from the cold, so that they fall an easy prey to cod.

In Viilsund in the Limfjord a large number of dead sprats drifted ashore after the ice had disappeared in the spring of 1929, and in other places in the Fjord dead sprats were observed during the ice-period in Jan.—March.

[1]) See the footnote p. 84.

Sprats are reported to have died *en masse* in the Isefjord in a previous severe winter (1911—12).

Several of the goby species have evidently suffered a good deal from the cold period in the winter of 1928—29, and in particular information has been received as to the wholesale destruction amongst black gobies (*Gobius niger*) in several different localities.

The climatic stamp of the saltwater fish which, it has been established, have died *en masse* in the waters around Denmark in the winter of 1928—29, will be seen from the table below giving the temperature of the spawning places of the different species:

	Approximate values for the temperature (°Celsius) of the spawning places of the species in the spawning season
Eel, *Anguilla vulgaris*	14—19[1])
Tunny, *Orcynus thynnus*	11—18
Black goby, *Gobius niger*	7—18
Double spotted goby, *Gobius ruthensparri*	7—18
Turbot, *Rhombus maximus*	7—18
Sole, *Solea vulgaris*	7—18
Sprat, *Clupea sprattus*	6—18
Three-spined stickleback, *Gasterosteus aculeatus*	4—20
Flounder, *Pleuronectes flesus*	4—13
Haddock, *Gadus æglefinus*	4—12
Lump-fish, *Cyclopterus lumpus*	3—15
Herring, *Clupea harengus*	3—14
Plaice, *Pleuronectes platessa*	2—12
Cod, *Gadus callarias*	1—12
Viviparous blenny, *Zoarces viviparus*	0—14
Common sea scorpion, *Cottus scorpius*	0—11

It is obvious that the mortality amongst the species which require a relatively high temperature at the spawning season (over 5° C.) has been larger than amongst the species which can spawn when the temperature is relatively low (under 4° C.).

In the following we will consider the different species under separate headings:

Lump-fish (*Cyclopterus lumpus* L.).

From the winter of 1928—29 we possess no evidence as to any wholesale destruction amongst the lump-fish in the waters around Denmark, but in the winter

[1]) In giving this temperature it is assumed that the eel spawns at a depth of c. 200—400 metres in that region of the Atlantic Ocean where Johs. Schmidt has found its tiny larvae. (See Johs. Schmidt: The Breeding-Places of the Eel. Phil. Transact. Royal Soc. of London. Ser. B. Vol. 211. 1922.)

of 1925—26 a number of dead or dying lump-fish were taken up in the brash in the western portion of the Limfjord.

Black Goby (*Gobius niger* L.).

From the winter of 1928—29 we possess reports as to the occurrence of a strikingly large number of dead black gobies in different localities: Thisted Broad, Skive Fjord, Aunø Fjord, and the waters between Glænø and Sealand. At the two former localities the dead black gobies were taken up in different implements; in the last-mentioned localities they were observed lying on the sea-bottom.

Double-spotted Goby (*Gobius ruthensparri* Euphrasén).

From only one place have we received a report as to gobies perishing *en masse* in the winter of 1928—29, viz. from Havnsø on the north-west coast of Sealand. Mr. Carl Willadsen, fisherman, saw this species frozen fast in the ice by the hundreds.

The mean salinity of the water is here about 16—17 per mille in the winter.

Common sea scorpion (*Cottus scorpius* L.).

Dead sea scorpions have only been reported from a single locality in the winter of 1928—29, namely from Holsteinborg Cove at Bisserup. Mr. Albert Nielsen, fisherman, observed here several dead sea scorpions on the sea-bottom together with numerous dead eels, flounders, sticklebacks, black gobies, etc. after the ice had disappeared.

The mean salinity of the water is here c. 14 per mille.

Three-spined stickleback (*Gasterosteus aculeatus* L.).

Only from a single locality has information been received as to the occurrence of dead sticklebacks in the winter of 1928—29, viz. in the waters between Glænø and Sealand. Mr. Albert Nielsen observed a number of dead sticklebacks lying here on the sea-bottom together with many other dead fish after the ice had disappeared.

Viviparous blenny (*Zoarces viviparus* L.).

Dead viviparous blennies have been reported from the Limfjord and Ringkøbing Fjord, and the waters between Glænø and Sealand, lying on the sea-bottom during the ice-period in Jan.—April 1929. The stock as a whole has, however, probably suffered no great injury. A number of fry have developed in the course of the winter, but the 1929 year class promises to be less abundant than normally.

Tunny (*Orcynus thynnus* L.).

Immediately after the end of the ice-period in the spring of 1929 two dead tunnies drifted ashore at Kronborg Head. These specimens had undoubtedly spent the winter in the inner Danish waters.

In 1928 and 1929 a striking number of tunnies appeared in the inner Danish waters.

Perch (*Perca fluviatilis* L.).

When the ice disappeared from Nakskov Fjord in the spring of 1929, dead perch and eels were found lying on the fjord-bottom (44). The mean salinity of the water in Nakskov Fjord is c. 10—13 per mille, and perch are only rarely met with in water of higher salinity.

After previous severe winters it has been observed that dead perch have drifted in large numbers on to the shores of Dybsø Fjord (79).

Cod (*Gadus callarias* L.).

From the information given in Chapter III it is clear that the cod stock as a whole has not suffered any particular injury from the severe and protracted period of cold in the waters around Denmark in the winter of 1928—29. The reports received by us show that a wholesale destruction of cod occurs especially when stormy weather sets in during a cold period, so that the water becomes extremely cold right down to the bottom. As a rule this wholesale destruction occurs only in very shallow water (less than 10 metres in depth), and it is particularly the cod caught in weels which are liable to be killed by the cold.

In the weels placed under the ice there is far less mortality among cod than among eels.

Immediately after the disappearance of the ice in the spring of 1929 a considerable number of fairly large dead cod were taken up during fishing operations with the Danish seine in the following localities:

1) In Sønderborg Bay off Skelde Bro at 28 metres' depth
2) S. of Als outside Hørup Hav at 34 metres' depth
3) SW. of Vodrups Flak at 26 metres' depth
4) E. of Als off Mommark at 36 metres' depth
5) At Barsø at 20 metres' depth.

As has been already mentioned (pp. 84—85), wholesale destruction among the fish in these localities has been undoubtedly due to a deficiency of oxygen or possibly to the formation of sulphuretted hydrogen in the water.

In the Danish waters (with the exception of Bornholm Deep) the cod spawn chiefly in February, March, and April. On account of the intense cold in the winter and spring of 1929 the spawning was delayed and the growth of the

larvae checked. Even at the end of May and the beginning of June not a few cod larvae were found of under 10 mm. in length in the Belt Sea and the western Baltic.

Haddock (*Gadus æglefinus* L.).

Immediately after the ice had broken up in the spring of 1929, a considerable number of dead haddock of a good size were taken up during fishing operations with the Danish seine at the following places E of Slesvig:

1) In Sønderborg Bay off Skelde Bro at 28 metres' depth
2) S. of Als off Hørup Hav at 34 metres' depth
3) E. of Als off Mommark at 36 metres' depth
4) At Barsø at 20 metres' depth.

No large number of dead haddock have been observed in other places in the waters around Denmark in the winter of 1928—29, and the great mortality at the above-mentioned places was undoubtedly caused by a deficiency of free oxygen in the water (see pp. 84—85).

The report quoted in Chapter III (p. 74) that, during an easterly storm in frosty weather in the winter of 1925—26, a number of haddock had been cast up on to the shores of Lille Belt indicates that when a storm sets in during a cold period the haddock which are in shallow water may be killed by the cold.

Turbot (*Rhombus maximus* L.)

After the ice had disappeared in the spring of 1929, a large number of small dead turbot of about 12 cm. average length were taken up along the shores of the northern Kattegat (23).

On the other hand, no dead turbot in any appreciable numbers have been taken up during fishing operations with trawl and Danish seine in the waters around Denmark.

Plaice (*Pleuronectes platessa* L.).

The stock of plaice in the waters around Denmark has evidently not suffered to any great extent during the severe period of cold in the winter of 1928—29, if we except the fry. Only in the waters around Als, after the ice had disappeared in the spring of 1929, were a considerable number of dead plaice taken up from the sea-bottom, together with dead flounders, haddock, cod, and a few sea-trout. As has already been mentioned (pp. 84—85) it is probably the deficiency of oxygen which has caused the wholesale destruction of the fish.

After the ice had disappeared in the spring of 1929, some dead plaice, c. 11—19 cm. in length, drifted up on to the shores of Aalbæk Bay.

Only small quantities of plaice fry developed in the southern Kattegat, the Belt Sea, and the western Baltic in the spring of 1929. The plaice spawn in these

waters chiefly in January, February, and March, but on account of the cold the spawning was delayed, so that it took place for the most part in March and the beginning of April. The larvae did not as a rule appear until April, but there was only a little plankton in the water even in April, owing to the low temperature and the ice which had previously covered the water, and the tiny larvae undoubtedly perished *en masse*.

The comprehensive investigations, carried out in the summer of 1929 by the Danish Biological Station, have shown that there were unusually few young plaice of the year class 1929 in the southern Kattegat, Belt Sea, Sound, and adjoining parts of the Baltic.

Similar conditions have been noted after former cold winters[1]).

Flounder (*Pleuronectes flesus* L.).

After the ice had disappeared in the spring of 1929, a considerable number of dead flounders were observed in several places lying on the sea-bottom in our inlets in quite shallow water, e. g. in the waters between Glænø and Sealand, in Ringkøbing Fjord, and in Nymindestrømmen S. of the dam. In these places the flounders were undoubtedly frozen to death. In Flensborg Fjord and at several spots in the waters around Als a considerable number of dead flounders were taken up during operations with the Danish seine from depths of 20—36 metres after the ice had disappeared. At these last-mentioned places the flounders probably died through lack of oxygen (see pp. 84—85).

It was noticed in several places where fishing operations had been carried on in the winter of 1928—29 with gill nets under the ice, that the flounders died comparatively quickly after being caught.

As a whole the flounder stock in the waters around Denmark has evidently suffered no great damage during the severe winter of 1928—29.

Sole (*Solea vulgaris* Quensel).

A number of Danish cutters which carried on fishing operations with the Danish seine in the eastern and south-eastern parts of the North Sea at depths of c. 25—50 metres (see p. 85) took dead soles up in their seines in the last half of March and throughout the whole month of April. The fishermen assumed that death had been due to the low temperature, which is probably correct.

The Danish sole fishery along the west coast of Jutland which is carried on chiefly in May and June, was a complete failure in 1929, while there seem to have been more soles than normally in the deeper water in the North Sea in March and April. It seems therefore likely that the low temperature in the coastal regions in

[1]) A. C. Johansen: On the Fluctuations in the Quantity of young Fry among Plaice etc. Report XXXIII of the Danish Biological Station. 1927.

the eastern and south-eastern parts of the North Sea in the spring of 1929 has hindered the soles' normal migrations from deep to shallower water in spring[1]).

Communications have been received to the effect that Danish fishermen in the Kattegat took up only a few dead soles in their fishing gears after the ice had disappeared in the spring of 1929. The stock of soles thus seemed to have suffered less in the Kattegat than in the North Sea.

Eel (*Anguilla vulgaris* Turton).

Of all species of fish it is obviously the eel which suffers most from severe winters in the waters around Denmark. We have received information from many different places that dead eels have been observed, and from still more places that the eels during the severe period of cold in Jan.—April 1929 were "feeble", "tame", "sluggish", "blind", or "diseased". One might think that there was nothing particularly serious in the eels becoming "feeble" during the winter cold, but experience has shown that these feeble eels often fall a prey to large cod.

After the end of the severe winter 1923—24 Dr. Blegvad observed (on April 30th, 1924) that in the stomach of a large cod, 89 cm. in length, caught in Nyborg Fjord, there were 8 large eels. Since it is not usual for cod under natural conditions to devour large eels, there is every reason to suppose that the eels in question had been feeble on account of the acute winter cold, and that the cod accordingly found them an easy prey. The following report, sent us by Mr. J. M. Rasmussen, fisherman, Fredericia (94), points to the same conclusion:

"The eel is the fish which suffers most here during ice-periods. When fishing operations are carried on with the Danish seine or otter seine on the last few days before the water is covered with ice, the cod which are caught are full of eels, and feeble eels are now and then taken up with the seines. The same occurs just after the ice has gone."

Although the eel stock in the Danish waters has certainly as a whole not suffered any serious damage during the cold period in Jan.—April 1929 it is, however, clear that the weakening effect on the stock has diminished the yield of the fishery to some extent and will continue to diminish it for the next few years. The fact that the eel stock in freshwater suffers still more from a cold period than does the eel stock in salt and brackish water contributes towards this result. Many of the eels in our inlets are evidently killed by intense cold, whilst others are suffocated through lack of oxygen when the waters are covered with ice for a long period.

Pike (*Esox lucius* L.).

After the ice had melted away in the spring of 1929, a large number of pike fry were observed in Stege Nor, lying dead on the sea-bottom. The mean salinity of the water in Stege Nor is c. 6—8 per mille.

[1]) Cfr.: A. C. Johansen: Marking Experiments with Sole etc. Medd. Komm. f. Havundersøgelser, Ser. Fiskeri. Bd. V. 1916.

In former severe winters a number of dead pike were observed in the waters S. of Sealand. In these waters it happens not infrequently that wholesale destruction among pike is called forth by another factor than low temperature, namely by a sudden influx of relatively salt water from the Great Belt, caused by violent westerly storms. In these waters where the mean salinity is about 9—10 per mille, there is a large pike stock which no doubt in the main develops in Stege Nor. It is probable that the effects of the considerable mortality among the pike fry in Stege Nor in the spring of 1929 will be felt also in the waters S. of Sealand.

Sea-trout (*Salmo trutta* L.).

After the ice had disappeared in the spring of 1929, dead sea-trout were found in several different localities, namely:

In Norsminde Fjord, several specimens
S. of Als at c. 34 metres' depth, 3—4 large specimens
In Sønderborg Fjord off Skelde Bro at 28 metres' depth, 1 specimen.

At the two last-mentioned localities the sea-trout were taken up from the sea-bottom with the Danish seine, together with large numbers of dead cod, haddock, plaice, and flounders (63). The cause of the mortality in these localities was probably lack of oxygen.

During a period of frost in the spring of 1920 numerous sea-trout were killed which had made their way into Struer Harbour in the Limfjord. About 100 of them were taken up with katcher in the harbour (89).

Sprat (*Clupea sprattus* L.).

After the ice had broken up in the Limfjord in the spring of 1929, large numbers of sprats, frozen to death, were observed lying on the beach at Viilsund. There were enough sprats to fill many boxes but they were not in sufficiently fresh condition to be suitable for marketing.

At other places in the Limfjord, namely in Oddesund and at Fur, a number of dead sprats were observed amongst the ice. We possess no reports from the other Danish waters as to any wholesale destruction of sprats in the winter of 1928—29. On the other hand large numbers of dead sprats were found in the Isefjord during a period of hard frost in January 1912 (20, 90).

Herring (*Clupea harengus* L.).

According to reports from various quarters, some small herring were found among the dead sprats which had drifted ashore at Viilsund in the spring. Dead herring were also observed during the ice-period in Jan.—March 1929 in Oddesund

and at Fur. In previous ice-winters a few small dead herring were observed amongst and on the ice flakes in Thyborøn Canal (9), and it was reported that a large number of young herring perished in the Isefjord during a period of hard frost in January 1912 (90).

C. Crustaceans.

Among certain crustaceans there has evidently been here and there an unusually great mortality in the winter of 1928—29, but there is probably no reason to suppose that the stock as a whole has suffered any appreciable injury from the cold.

Livid swimming crab (*Portunus holsatus* Fabr.).

After the ice had disappeared from off the west coast of Jutland in the spring of 1929, large numbers of dead crabs were washed ashore at Nymindegab. According to reports from Mr. Bloch (5) 2—3 cartloads of these crabs lay along a short stretch of coast, 2—3 kilometres S. of Nymindegab. By far the greater part consisted of svimming crabs, some were crab-fish, and there were a few sand-crabs (*Hyas*).

Crab-fish (*Cancer pagurus* Leach).

During fishing operations carried out from Thyborøn and Harboøre in the North Sea near the west coast of Jutland, a surprisingly large number of dead crab-fish were taken up in the early spring of 1929 (7). A number of crab-fish were also found amongst the many swimming crabs which drifted ashore on to the west coast at Nymindegab, after the ice had disappeared in the spring of 1929.

Common sand-crab (*Hyas araneus* L.).

Some dead sand-crabs were found amongst the many dead svimming crabs which drifted ashore on to the west coast of Jutland at Nymindegab, after the ice had disappeared in the spring of 1929.

Lobster (*Homarus vulgaris* M. Edw.).

According to a report from Mr. P. Petersen, fishery official, Struer, a number of dead lobsters were found to have drifted up on to the shores of Venø Bay along the line Vodstrup—Hjerm—Handbjerg, after the ice had disappeared in the spring of 1929. It was not the sloughs of lobsters which were observed but the dead animals themselves. They had probably been frozen to death. — Alf Dannevig writes (loc. cit.) that he has never heard of lobsters being frozen to death on the coasts of Norway.

Common Shrimp (*Crangon vulgaris* Fabr.).

We possess only one report as to shrimps perishing *en masse* in the winter of 1928—29. This report was sent in by Mr. Albert Nielsen, fisherman, Bisserup,

who found many shrimps lying dead on the sea-bottom after the ice had disappeared from the waters between Glænø and Sealand.

Prawn (*Palæmon* (*Leander*) *fabricii* Rathke).

We possess evidence that when the ice disappeared from the waters between Glænø and Sealand in the spring of 1929, a number of dead prawns were found on the sea-bottom (69). We are also informed that when the weels which had been placed under the ice in Karebæk Fjord were taken up, a number of dead prawns were enmeshed in them. It is impossible to judge from the information received whether the winter cold in certain places has destroyed the stock of prawns to any appreciable extent or not.

On the whole the yield of the prawn fishery in the summer of 1929 was satisfactory, but in certain places, e. g. in the Smaaland Sea, the Sound, the Kalveboder, and the Isefjord it was far below normal.

Common sand-skipper (*Gammarus locusta* L.).

After the ice had disappeared in the spring of 1929, vast numbers of dead *Gammarus* were observed on the shores of Roskilde Fjord and at Havnsø on the north-west coast of Sealand.

The sand-skipper is an important food animal for many species of fish, such as the eel, young cod, flounder, dab, viviparous blenny, etc.

On the other hand it does harm by gnawing fishing nets to pieces. In the severe winter of 1928—29 it ruined several gill nets in Ringkøbing Fjord. Mr. Jørgensen Sørensen, fishery official, Ringkøbing, gives us the following information in this connexion: "The sand-skippers ruined the gill nets by actually gnawing the inner parts into pieces so that only the frame ropes were left[1])."

[1]) Cp. H. C. Redeke en A. P. C. de Vos: Rapport over onderzoekingen betreffende de schade, veroorzaakt aan fuiken door de zoogenaamde "Zijbijters" en "Snellen". Verslagen en Mededeelingen van de Afdeeling Visscherijen No. 7. S'Gravenhage. 1924.

List of Informants regarding the Occurence of dead Marine Animals in Severe Winters.

1 Fisker Chr. Andersen, Sundgade 60, Sønderborg.
2 Chr. Andersen, Fmd. f. Gilleleje Fiskeriforening, Gilleleje.
3 Fisker Peter Andersen, Fmd. f. Isefjordens Fiskeriforening, Holbæk.
4 Fisker G. W. Baatz, Fmd. f. Hansted Fiskeriforening, Hansted Fyr, Hanstholm, Thisted.
5 Rentier N. Bloch, Nymindegab pr. Nørre Nebel.
6 Fisker Christen Bom, Fmd. for Fur Fiskeriforening, Fur.
7 Havnebetjent Buus, Thyborøn.
8 Fisker Chr. Christensen, St. Pauls Allé 12, Boldesager, Esbjerg.
9 Styrmand H. C. Christensen, Redningsdamperen »Vesterhavet«, Esbjerg.
10 Skipper Rasmus Christensen, Fmd. f. Sæby Fiskeriforening, Havnen, Sæby.
11 Fisker Peter Dall, Fmd. f. Aabenraa og Omegns Fiskeriforening, Aabenraa.
12 Fisker Gustav Didriksen, Fmd. f. Kolding og Omegns Fiskeriforening, Strandhuse, Kolding.
13 Fisker Albert Ditlevsen, Fmd. f. Karebæk Fj. og tilgr. Vandes Fiskerif., Karebæksminde.
14 Fisker Chr. Nielsen Dragsbæk, Fmd. f. Klitmøller Fiskeriforening, Klitmøller, Thisted.
15 Fiskeriassistent P. F. Erichsen, Aabenraa.
16 Fiskeribetjent H. Esager, Staby pr. Ulfborg St.
17 Fisker I. P. Fisker, Fmd. f. Hjarbæk og Omegns Fiskeriforening, Hjarbæk pr. Løgstør.
18 Skipper Andreas Chr. Frandsen, Fmd. f. Thorøhuse og Omegns Fiskeriforening, Thorøhuse, Assens.
19 Fisker Frederik Frederiksen, Fmd. f. Reersø Fiskeriforening, Reersø, Gjørlev.
20 Fiskeribetjent H. I. Frederiksen, Lynæs.
21 Fisker Fr. Gottredsen, Botofte pr. Tranekær.
22 Fiskeribetjent Gerhardt, Svendborg.
23 Kutterfører Chr. Hansen, Frederikshavn, Fmd. f. Frederikshavns Fiskeriforening.
24 Fisker Hans M. Hansen, Fmd. f. Drejø Fiskeriforening, Drejø, Svendborg.
25 Fisker Jens P. Hansen, Fmd. f. Frederiksværks Fiskeriforening, Strandvejen 18, Frederiksværk.
26 Fisker Laurits Hansen, Fmd. f. Ebeltoft Fiskeriforening, Ebeltoft.
27 Fisker Mads Hansen, Fmd. f. Spodsbjerg og Omegns Fiskeriforening, Spodsbjerg St.
28 Fisker Niels Hansen, Fmd. f. Nyord Fiskeriforening, Nyord pr. Stege.
29 Fisker Valdemar Hansen, Fmd. f. Nørre Lyngby Fiskeriforening, Nørre Lyngby, Vittrup.
30 Fisker Andreas Hejlesen, Fmd. f. Hirtshals Fiskeriforening, Hirtshals.
31 Fisker Axel Henriksen, Medl. af Dansk Fiskeriforenings Bestyrelse, Gl. Tappernøje.
32 Fisker E. I. Høj, Fmd. f. Nymindegab Fiskeriforening, Nymindegab pr. Nørre Nebel.
33 Fisker Lauritz Nissen Høi, Fmd. f. Mjels og Omegns Fiskeriforening, Holm pr. Nordborg, Als.
34 Fisker H. P. Jacobsen, Errindlev Havn, Laaland.
35 Fiskeribetjent Axel Jensen, Thisted.
36 Fiskeribetjent Bagger Jensen, Karebæksminde.
37 Fiskeribetjent F. Jensen, København.
38 Fiskeribetjent H. M. Jensen, Grenaa.
39 Skipper Ludvig A. Jensen, Fmd. f. Strandby Fiskeriforening, Strandby pr. Frederikshavn.

40 Fiskeriassistent J. Jensen, Nykøbing M.
41 Kutterfører Søren Jensen, Grenaa.
42 Fisker Julius Johannesen, Fmd. f. Snekkersten og Skotterup Fiskeriforening, Snekkersten.
43 Fisker Hans Johansen, Fmd. f. Helsnæsbugt, Brunshus og Omegns Fiskeriforening, Brunshus pr. Ebberup.
44 Fiskerifoged Julius Juul, Fmd. f. Nakskov og Omegns Fiskeriforening, Langø pr. Kappel.
45 Fisker Andreas Jørgensen, Engholmstrand pr. Nørre Sundby.
46 Hans Jørgensen, Fmd. f. Gennerbugts Fiskeriforening, Kalvø pr. Genner.
47 Fisker J. H. Jørgensen, Fmd. f. Faaborg og Omegns Fiskeriforening, Dyreborg, Faaborg.
48 Fisker J. Jørgensen, Fmd. f. Assens og Omegns Fiskeriforening, Assens.
49 Fisker Andreas Koch, Medl. af Dansk Fiskeriforenings Bestyrelse, Gudhjem, Bornholm.
50 Fisker Rikard Krintel, Fmd. f. Vejle Fjords Fiskeriforening, Bredballestrand, Vejle.
51 Fisker Ole J. Kristiansen, Fmd. f. Esbjerg Fiskeriforening, Esbjerg.
52 Fiskeribetjent Vilh. Kristiansen, Fmd. f. Bornholm og Christiansø Fiskeriforening, Rønne.
53 Fisker Laurits Karl Kyndi, Fmd. f. Hannæs Fiskeriforening, Arup pr. Vesløs.
54 Fisker N. P. Landt, Fmd. f. Nysted Fiskeriforening, Nysted.
55 Fiskeribetjent Chr. Larsen, Bogense.
56 Fiskeribetjent Chr. Th. Larsen, Masnedsund.
57 Fisker Holger Larsen, Fmd. f. Thisted Fiskeriforening, Thisted.
58 Fisker J. S. Larsen, Fmd. f. Hadsund Fiskeriforening, Brolykke, Hadsund.
59 Fisker H. C Madsen, Fmd. f. Det nordlige Stevns og Omegns Fiskeriforening, Strøby Ladepleds, Strøby.
60 Fiskeeksportør Martens, Karebæksminde.
61 Fiskeeksportør M. Munk Madsen, Fmd. f. Vorupør Fiskeriforening, Nørre Vorupør pr. Sjørring.
62 Fisker Chr. Meyer, Fmd. f. Korsør Fiskeriforening, Korsør.
63 Fisker Jens Michaelsen, Fiskerikontrollen, Aabenraa.
64 Fisker Chr. Mikkelsen, Fmd. f. Fiskeriforeningen f. Skærbæk og Omegn, Skærbæk pr. Taulov.
65 Fisker Jens Mikkelsen, Fmd. f. Norsminde Fiskeriforening, Norsminde, Malling.
66 Fisker M. K. Mikkelsen, Fmd. f. Fiskeriforeningen for Sønder Nissum Fjord, Staby pr. Ulfborg St.
67 O. Morsø, Fmd. f. Marstal Fiskeriforening, Marstal.
68 Fisker Hans Møller, Aarsdale pr. Svaneke, Bornholm.
69 Fisker Albert Nielsen, Bisserup pr. Rude.
70 Fisker Chr. Nielsen, Fmd. f. Middelfart Fiskeriforening, Teglgaard, Middelfart.
71 Fisker Hans Nielsen, Egernsund.
72 Fisker Hans Chr. Nielsen, Fmd. f. Roskilde og St. Jørgensbjerg Fiskeriforening, Karen Olsdatterstræde 3, Roskilde.
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74 Fisker Jens Nielsen, Fmd. f. Rødvig og Omegns Fiskeriforening, Rødvig.
75 Fiskeribetjent K. Nielsen, Frederikshavn.
76 Anders M. Nielsen, Fmd. f. Sejrø Fiskeriforening, Sejrø, Aasen pr. Kalundborg.
77 Fisker Niels Nielsen, Fmd. f. Udbyhøj — Syd og Nord — Fiskeriforening, Udbyhøj pr. Havndal.
78 Fiskeribetjent O. Nørgaard, Aarhus.
79 Fisker Hans Vald. Olsen, Fmd. f. Aunø Fjords og tilgr. Vandes Fiskeriforening, Sallerup pr. Lundby.
80 Fisker Johan Chr. Pedersen, Fmd. f. Skagens Fiskeriforening, Søndervej, Skagen.
81 Fisker Marius Pedersen, Fmd. f. Dokkedal Fiskeriforening, Dokkedal pr. Gudumholm.
82 P. Pedersen, Fmd. f. Lohals Fiskeriforening, Lohals.
83 Fisker Rasmus Pedersen, Fmd. f. Anholt Fiskeriforening, Anholt.
84 Fisker S. Reinhold Pedersen, Fmd. f. Hals og Omegns Fiskeriforening, Hals.
85 Kutterfører Jesper Peitersen, Fmd. f. Lemvig og Omegns Fiskeriforening, Lemvig.
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88 Fisker Chr. Nøiers Petersen, Fmd. f. Horsens og Omegns Fiskeriforening, Fjordsgade 49, Horsens.
89 Fiskeribetjent P. Petersen, Struer.
90 Fisker Svend Petersen, Fmd. f. Lynæs Fiskeriforening, Elmely, Lynæs.
91 Fisker Anders Rasmussen, Skovshoved pr. Charlottenlund.
92 Fisker Chr. Rasmussen, Fmd. f. Agersø Fiskeriforening, Agersø, Sj.
93 Fisker H. P. Rasmussen, Fmd. f. Bandholm og Omegns Fiskeriforening, Havnegade. Bandholm.
94 Kutterfører M. J. Rasmussen, Fmd. f. Fredericia og Omegns Fiskeriforening, Fredericia.
95 Fisker Rasm. Jørgen Rasmussen, Fmd. f. Svendborg Fiskeriforening, Thurø, Svendborg.
96 Skipper L. Rungborg, Dejret pr. Knebel.
97 C. M. Bruun Sandsgaard, Fmd. f. Aalborg og Omegns Fiskeriforening, Gjøl pr. Aabybro.
98 Fiskeribetjent Skaanning, Randers.
99 Fisker Jørgen Skelgaard, Fmd. f. Sottrupskov Fiskeriforening, Sottrupskov pr. V. Sottrup.
100 Fisker Jørgen Snitkjær, Aarø pr. Aarøsund.
101 Fiskeribetjent Jørg. Sørensen, Ringkøbing.
102 Fisker Niels Thomasen, Fmd. f. Skive og Omegns Fiskeriforening, Havnen, Skive.
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107 Fisker Olaf Vinther, Fmd. f. Onsevig Fiskeriforening, Onsevig.
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IV.

Studies on the Biology of the Oyster *(Ostrea edulis)* VI—VIII.

By

R. SPÄRCK

VI. Some Observations on the Spawning of *O. edulis* in the Limfjord, with special Reference to the Problem of Lunar Periodicity.

Since my investigations of the breeding of oysters in the Limfjord were published in 1924, the spawning of *O. edulis* has been treated in several papers, some of which are of interest also to the spawning conditions in the Limfjord. I shall first mention I. H. Orton's paper (1926) on the Lunar Periodicity in Spawning of Oysters. According to Orton a certain coincidence between the spawning of oysters and the lunar phases was proved, at any rate in 1926, in that the spawning mainly took place when the moon was full. I. H. Orton declares himself unable to give a definite explanation of the causes of this phenomenon, he discusses a series of possibilities, and in this connection sets forth the theory that the phenomenon may be due to the tides with ensuing alterations in the food supply. The tides being rather inconsiderable in the Limfjord it might be of interest to observe whether any lunar periodicity in the spawning of the oysters in this water could be stated. There is as a rule only one spawning period in the Limfjord, only in warm summers it seems that more than one, at any rate two such periods may occur. During the years 1919—21, the spawning period occurred in the two first years at about June 1st, in 1921 in the last week of May. In 1919 the moon was full on June 13th, in 1920 on June 1st, and in 1921 on May 21st. In order to have this problem fully cleared up I examined some oysters in 1928 when a later spawning period occurred in September, and it appeared that among 94 oysters of the same year class, which were taken on the first day after the new moon, 10,5 per cent. were spawning, whereas only 1,5 per cent. of 200 oysters of the same year class, taken in the same locality, were spawning at the next full moon. This means that in, at any rate, two years, 1919 and 1928, a maximum spawning has been ascertained at new moon, and that a regular lunar periodicity in the spawning of the oysters in the Limfjord is out of question. This is, however, no proof that such coincidence does not occur in other localities, and its wanting in the Limfjord with its unimportant tides seems to indicate that the cause of this lunar periodicity in the spawning of marine animals — if duly confirmed — is probably to be looked for in the direct or indirect effect of the tidal phenomena.

There can hardly be any doubt that there is a periodicity in the spawning of the oyster. In the Limfjord attention was not formerly drawn particularly to this

fact, there being, as said above, only a single spawning period most often in the month of June, in some few years at the end of May, in a few others at the middle of July. As stated by me on a previous occasion (1924, p. 17) it has been regarded as an exceedingly rare occurrence to find spawning oysters in the Limfjord in September.

After 1922 when the transplanting of Dutch oyster spat into the Limfjord was started, it has, however, appeared that among these latter spawning often takes place in September, whereas no spawning worth mentioning occurs in September in the native stock of oysters in the Limfjord, not even in the years when spawning occurred among the small relaid Dutch oysters. This was, indeed, the case in 1928 when 10,5 per cent. of the Dutch oysters were spawning whilst no spawning at all was found to occur in the native stock of oysters in the Limfjord, although a similar number of these latter from the same locality were opened. On the other hand, just the opposite has been observed, in that the native stock of oysters in the Limfjord has been found to be spawning in summers when no spawning takes place among the relaid Dutch oysters. Of 52 native oysters in the Limfjord, which had been dredged in Nissum Broad on July 15th—16th, 1927, three, i. e. 6 per cent., were found to be spawning, whereas not a single one of 75 relaid Dutch oysters from neighbouring localities was spawning at that time of the year. The explanation of this fact most probably is that the native stock of oysters in the Limfjord mainly consists of year classes, totally different from those of the relaid Dutch oysters. These latter are quite young, 2—4 years old, whereas the native Limfjord stock contains all year classes up to those of 12—15 or still more years. Under otherwise similar conditions it must no doubt be supposed that the old oysters spawn first, the younger ones somewhat later. In waters with a temperature more favourable to the propagation of oysters than that of the Limfjord it is to be expected that rather good oyster years, i. e. years in which the stock is renewed by a considerable percentage, will become frequent, and this will further result in a stock consisting of some pronounced year classes. These year classes then will spawn in the course of summer at certain intervals, thereby causing a distinct periodicity, corresponding to the spawning at different times of the native old stock in the Limfjord and of the relaid young oysters.

That it is the question of a periodicity having its cause in the different spawning periods of the year classes was confirmed by experiments in tanks from which it appeared that the old oysters are the first to spawn, the young one the last. This is certainly the cause of the fact that when oysters are exposed to feeding difficulties through rising temperatures the old oysters die off first, the young ones later, which has likewise been confirmed through numerous observations in tanks as well as in the Norwegian oyster pools. Towards spawning time extraordinary demands of nourishment are put to the oyster, as the mother oysters produce such an amount of eggs that their weight may surpass that of the mother animal without the shell. In one case I found that an oyster, without shell having a weight of 2.5 g.,

produced 3 cm³. of eggs. It certainly is beyond any doubt that, as repeatedly pointed out by Orton, the conditions of nourishment have much influence on the propagation of the oyster and also on the sex change, even if this latter is to a great degree dependent on the regulating influence of the temperature. Through investigations of the Norwegian oyster pools I have had an opportunity of making experiences in that direction, concerning which I shall, however, have to refer to a publication which is in preparation. It appeared from these investigations that the influence caused by the temperature on the rhythm of sex change and propagation is more marked and makes itself much more felt in waters as for instance the Limfjord, in which the oyster lives near by the temperature limit of its propagating capacity, than in waters with a temperature in which the other factors are more predominating.

VII. Some Observations on the Influence of Temperature on Pelagic Larvae and their uptake of Oxygen.

In 1916 Hagmeier set forth the theory that one of the causes of the favourable influence of high temperature on the renewing of an oyster stock might be due to the fact that the growth rate of the larvae must be considered to be strongly depending on the temperature. Through different observations in nature as well as in tanks (Spärck 1924 and 1927) I am able to confirm this theory. According to the experience obtained by these observations I came to the conclusion that in cool summers only little fry was produced and the growth of these larvae very slow, whereby their pelagic stage became of so long duration that only a very small percentage of larvae were able to survive. Another possibility was that the effect of the low temperature might in itself be noxious or even killing to the larvae. In order to have this thoroughly cleared up I made some attempts in the Zoophysiological Laboratory of the University at keeping larvae of *Ostrea edulis* alive during long periods at different temperatures. I had already formerly had an opportunity of learning that oyster larvae are able to stand a refrigeration to temperatures of about 0° C. for at any rate a short space of time, as it had been proved that the larvae were easily transported and kept alive for 24—48 hours in quite small glasses, placed in Dewar's vessels with water at 0° C.

The larvae were obtained in the following way: a great number of oysters were examined till I succeeded in finding some bluesick oysters. This fry was then removed from the mantle cavity of the mother animal and placed partly in large glass vessels, partly in flat Petri bowls. In the first instance many larvae were put together, in the last only few larvae were isolated. The vessels were then placed into refrigerators adapted to keeping a constant temperature. In view of a possible infection in the vessels the water was frequently changed (every 2nd or 3rd day). In any case water of the same salinity, abt. 33 $^0/_{00}$, was used. The following attempts were made:

1) All larvae from one mother oyster were placed in a glass vessel, at 5° C., from August 16th—25th; on August 26th the water was for some hours cooled down to below freezing point (÷ 2° C.) and the temperature then increased to 2° C. The larvae were alive and able to swim about till September 25th.
2) Some larvae were placed at 5° C. from September 17th—October 15th. They were then isolated in smaller vessels and placed at 1°—2° C. Lived till October 29th.
3) All larvae from one mother oyster were kept alive at 5° C. from August 16th—September 25th.
4) Some larvae were kept alive, isolated in small vessels at 5° C. from September 15th—October 15th.
5) Some larvae were isolated in small vessels at 10° and 12° C.; they were alive from September 25th—September 29th.
6) Some larvae were placed in an aquarium with flowing water at 18° C. They lived from September 25th—September 27th.

From these experiments it appears that it is possible to keep oyster larvae alive for 4—6 weeks at temperatures of about 1°—5° C., and that they can even stand a refrigeration of short duration down to at least ÷ 2° C. It may therefore be taken for granted that a cooling down to temperatures even about the freezing point is of no directly killing effect to oyster larvae, and that when their development is checked at lower temperatures (even already at about 15° C.) this must be due to the growth hampering effect of the low temperature.

It is a common experience that it is extremely difficult to keep larvae of *Ostrea edulis* alive for a longer period in aquaria with rather high temperatures. In this respect it differs somewhat from *O. virginica*. From the above mentioned small experiments it also appeared that it was impossible at higher temperatures (10°, 12°, 18° C.) to keep larvae alive for more than 8 days at the most. As I have already had an occasion to maintain (Spärck 1926) this is no doubt first of all due to the fact that the pelagic larvae of *O. edulis* particularly demand a suitable and abundant supply of food. It seems to me that our experiences from experiments made in tanks indicate that most other pelagic larvae are in this respect less exacting than the oyster larvae. As it might be of interest in this connection to know the size category of the uptake of oxygen of the pelagic larvae, I undertook some determinations of the uptake of oxygen together with the above mentioned small investigations. For this purpose a great number of larvae, whose volume was determined through a centrifugal machine, were placed in a closed bottle with water of 33 $^{0}/_{00}$ salinity and a known amount of oxygen; after the lapse of some time the amount of oxygen in the bottle was once more determined. The determination of oxygen was made according to Winkler's method, for the titration Rehberg's burette for micro-titration was used, whereby it became possible to use so small vessels that the amount of uptake could be stated. The bottle containing the larvae was placed in a water

bath holding at some experiments a temperature of 16° C., at others of 17° C. The larvae used for the experiments had for 10 days previous to the experiment been kept at a low temperature (5° C.) without any food supply.

Five experiments of this kind were made with larvae of two different mother oysters. The experiments gave the following results:

I. Larvae of one mother oyster, volume 0.5 cm³.

1 experiment, duration 1 hour, uptake 1.67 cm³. per hour per l.
2 — — 1 — — 1.06 - — —
3 — — 4 — — 0.56 - — —

II. Larvae of another mother oyster, volume 0.5 cm³.

1 experiment, duration 1 hour, uptake 1.23 cm³. per hour per l.
2 — — ½ — — 1.06 - — —

It appears from these experiments that, as regards the larvae of both mother oysters and all the experiments together, the uptake must be indicated as belonging to one and the same size category, and characterised as largest in each of the first experiments with larvae from each of the mother oysters. Later on the uptake became decreasing, no doubt on account of the gradually decreasing ciliary motion and probably also of some mortality among the larvae. As the vessel containing the larvae had a volume of 132 cm³. the uptake per kg. per hour must, if the specific gravity of the larvae is placed at 1, in the above mentioned experiments be stated to be from about 450 to about 100 cm³. O_2. This must be estimated as a very high degree of uptake. As far as I know, no determinations of the uptake of oxygen in pelagic larvae of other animals exist, but if the above mentioned results are compared with determinations of the uptake of oxygen of marine invertebrates, the size category of uptake of oxygen in larvae of *O. edulis* must be considered to be far beyond the usual size category of uptake in marine invertebrates. According to statements at hand concerning the uptake of oxygen of marine molluscs the uptake seems at a temperature of about 18° C. to belong to a size category of 5—15 cm³. per kg. per hour. It must, however, be observed that the weight of the shell is in the cases in question included in the weight of the animal, but even if that is deducted no size category of the uptake of oxygen above 50—100 cm³. per kg. per hour will be attained. The experiments with molluscs were undertaken on newly caught animals, whereas the oyster larvae had not had any food for 10 days previous to the experiments. In *Aplysia* the uptake of oxygen is, according to Cohnheim, in famished animals, at 16° C., about 20 cm³. per kg. per hour, in *Octopus vulgaris* (according to Vernon) about 90 cm³. per kg. per hour. There is, therefore, hardly any doubt that the uptake of oxygen in pelagic larvae of *O. edulis* must be stated to be rather considerable, compared with the uptake at similar temperatures in other marine invertebrates. This is in good agreement with the observations hitherto made at different experiments of breeding and in tanks, at which it has proved particularly difficult to feed the oyster larvae.

VIII. On Natural Mortality in the Oyster Stock of the Limfjord.

On previous occasions (Spärck 1924 and 1927) I have had an opportunity of discussing the natural mortality of the oysters in the Limfjord and of maintaining that this fact must be supposed to be of great importance and amounting to hardly less than 20 per cent. annually in certain winters — at any rate locally — even to a still higher percentage. Through the transplanting of oyster spat, especially Dutch ones, which has taken place in the Limfjord since 1922, an abundant material is, however, now at hand for a determination of the mortality among these relaid oysters. As the question of this natural mortality is not only theoretically interesting to the problem of natural mortality among the marine invertebrates, but also of practical importance to the rational oyster culture, I shall in the following briefly summarize the experiences concerning this problem gathered in the course of recent years.

The amount of mortality has at any rate been stated through experimental dredgings, whereby some hundred oysters were dredged on the ground in question, and among which the percentage of dead oysters was determined. As a rule it is possible from the growth of the shell, its overgrowing with Ascidiae, Barnacles etc., to determine when death has occurred.

In the spring 1922 200000 small Dutch oysters were relaid at Mullerne in Nissum Broad. After about a year a mortality of 20 per cent. was stated, on $^{9}/_{5}$, 1923. On $^{14}/_{9}$, 1923, the mortality had increased to 35 per cent., and two years later, on $^{25}/_{5}$, 1924, it had attained 50 per cent.

On $^{23}/_{3}$, 1923, 2000000 small Dutch oysters were relaid in Nissum Broad. One month after the relay, $^{9}/_{5}$, 1923, the mortality only amounted to 4 per cent., in the course of summer it increased to 7 per cent. ($^{14}/_{9}$, 1923). After the lapse of two years, $^{25}/_{8}$, 1925, the mortality of these oysters had attained 31—35 per cent., which makes, according to previous experiences, a very low per cent. of mortality in the course of two years.

Among the small oysters relaid in spring 1924 a great difference was apparent regarding the mortality in the two localities in which they had been relaid. In the most western locality at Røjensø Hage in Nissum Broad the mortality was already after 18 months ($^{25}/_{8}$, 1925) 34 per cent., whilst in the more eastern locality at Kallerup in Nissum Broad, it was at the same time of the year only 17 per cent.

As regards the oysters relaid in the spring 1925 it was a similar case. In the westernmost locality, Mullerne in Nissum Broad, the mortality was 15 per cent., $^{25}/_{8}$, 1925, whereas in the more eastern locality, at Flovlev in Nissum Broad, it was simultaneously only 10 per cent. In the winter 1925—26 there seems to have been hardly any mortality in the localities in question. On $^{23}/_{4}$, 1926, the mortality was at Mullerne 13 per cent., i. e. no increase at all had occurred in the course of winter,

at Flovlev it had increased to 14 per cent. In the course of the summer 1926 it again increased in the western locality from 13 per cent. to 16,5 per cent. On $^{15}/_{7}$, 1927, the mortality as regards the western and the eastern localities, was respectively 24 per cent. and 18 per cent.; on $^{31}/_{8}$ of the same year it had strongly increased to 26,5 per cent. and 38 per cent. respectively.

Among the small oysters relaid, $^{11}/_{4}$, 1926, the mortality was 3 per cent. already on $^{23}/_{4}$, 1926, in the course of summer it increased considerably, as it had attained 27 per cent. on $^{22}/_{9}$ of the same year. In the course of the winter 1926—27 the mortality increased very little, as it was 26 and 29 per cent. respectively on $^{16}/_{7}$, 1927, on the two grounds on which oysters had been relaid in the spring 1926. At the end of the summer 1927 the mortality again increased rather considerably in these localities, in the eastern one from 26,2 to 36,4 per cent., in the western from 29 to 43,2 per cent.

Among the small oysters relaid in spring 1928 there was again some difference in the percentage of mortality. Directly after the transplanting the mortality was as usual almost nil (1—3 per cent.). In the more western localities the mortality was on $^{18}/_{5}$ still 2—3 per cent., but in the easternmost it had increased to 15 per cent. One month later it is in the eastern locality 20 per cent., in the others constantly 2—3 per cent. At the end of summer ($^{3}/_{9}$, 1928) the mortality is in the western localities 16—17 per cent., in the eastern 20 per cent. In the winter 1928—29, a pronounced ice winter with freezing in the months January—March, there was, in contradistinction to the two preceding winters, some mortality, which rose in the eastern locality to 26 per cent., in the more western to 24 per cent. Although there was some mortality in the severe winter 1928—29 it was not considerable and did not by far attain the high percentage of mortality which was stated in the inner Limfjord after the ice winter of 1923—24 (See Biol. Stat. Ber. 32 p. 15).

Thus the mortality among the small Dutch oysters, relaid in Nissum Broad, appears most often to be rather inconsiderable, compared with the percentage stated by earlier investigations for the native stock of the Limfjord. Whilst on 23 grounds with relaid native oysters we had in the years 1912—25 on three of the grounds an annual mortality of above 30 per cent., and on 7 grounds an annual mortality of 20—25 per cent., we have on the above mentioned grounds with relaid Dutch oysters (12 in all) only 4 with 20—25 per cent. of mortality, on the others the percentage is at about 15—20. This is certainly first of all to be ascribed to the fact that we have to do with relatively young oysters among which the mortality is less than in the somewhat older stock on banks with relaid natives. That it is not the question of a special characteristic of the Dutch oysters, but without doubt a phenomenon appertaining to age, appears from the fact that on banks with relaid but older Dutch oysters mortality is much more considerable. Among the dredged relaid Dutch oysters those not having attained a suitable size for sale are sorted out and once more relaid. On these banks with a second time relaid oysters the mortality

usually is rather more considerable than that on the banks with young, recently relaid oysters. As an instance of this we may mention the summer 1928 when the mortality among the newly relaid oysters was 16—20 per cent., that of the once more relaid ones 28 per cent. As may be seen from the previously named percentage of mortality it increased rather markedly at the end of the summer 1927 in 4 different localities including the oysters relaid in 1925 and 1926. There was, on the contrary, no such special increase among the young oysters relaid 1927, the percentage of dead oysters being between 9 and 15 per cent. at the end of summer. Among the once more relaid oysters the mortality of the summer 1927 was, on the other hand, 19 and 21 per cent.

All these facts seem to me to indicate that the cause of the lesser mortality among relaid Dutch oysters in the Limfjord is mainly due to the fact that the stock of these grounds consists of much younger year classes than those of the former banks of relaid natives and especially than those of the native stock of the Limfjord itself. It is, however, possible that other factors are contributing to this lesser mortality, as for instance the very intense dredging which is now undertaken on these very limited grounds. Through this activity *Asterias rubens*, *Carcinus maenas*, *Mytilus edulis*, etc., species destructive to the oyster (as enemies or food competitors) have become strongly decimated in number in the areas now used for relaying. Experiences of these last years have proved that all talk of the dredging as harmful to the oysters must be stated to be wrong as this activity is on the contrary to be regarded as most favourable.

It has further appeared that the mortality among the relaid oysters is above all pertaining to the summer time. For several winters, as for instance those of 1925—26 and 1926—27, it seems that no mortality at all has been stated among these oysters. The mortality seemingly is the most effective towards the end of summer, and this appears to me once more to point in the direction of the theory, on several occasions maintained by me, that the mortality among the oysters (and probably among many other animals) must above all be due to lack of food. This is a fact which must necessarily be fatal to the oysters on the above mentioned grounds at the end of summer, as these young oysters — as mentioned in a preceding chapter — spawn very late in summer.

There is, however, also some variation according to locality. In certain years, for instance 1925, the mortality seems to have been most prominent in the westernmost localities, in 1928 in the eastern, which may be in relation to the current conditions during the years in questions, as these latter are, of course, of great influence to the food conditions. At other times, for instance the end of the summer 1927 with its above mentioned increase of mortality, this latter seems to have been equally prominent on all the grounds of Nissum Broad. Also in ice winters the mortality seems to be equal on all the different grounds.

From this little summary it should appear that among young oysters of 2—4 years the mortality is, on an average, somewhat lower than among older oysters,

usually 15—20 per cent. annually. Further that the abnormally high percentage (50—70 per cent.) of winter mortality, which was formerly stated from the inner part of the Limfjord, does not occur among these young oysters of the Nissum Broad. This must, presumably, partly be ascribed to the conditions of temperature in the Nissum Broad, partly to the young age of the oysters. Finally we have seen that by far the most prominent mortality among relaid oysters of the Nissum Broad is a summer mortality and in all probability to be referred to the food problem.

Litterature.

O. Cohnheim, 1911—12: Über der Gaswechsel von Tieren mit glatter und querstreifter Muskulatur. (Zeitschr. physiol. Chemie 76.)

A. Hagmeier, 1916: Über die Fortpflanzung der Auster und die fiskalischen Austernbänke. (Wiss. Meeresunters. N. F. Abt. Helgoland. 11.) Kiel & Lpz.

J. H. Orton, 1926: On a lunar periodicity in the spawning of normally grown Falmouth oysters (O. edulis) in 1925 with a comparison of the spawning capacity in normally growth and dumpy oysters (Journ. Mar. Biol. Ass. 14.) Plymouth.

R. Spärck, 1924: Undersøgelser over Østersens (Ostrea edulis) Biologi i Limfjorden, med særlig Henblik paa Temperaturens Indflydelse paa Kønsskiftet. (Rep. Dan. Biol. Stat. 30.) Copenhagen.

— 1926: On the food-problem in relation to marine zoogeography. (Physiol. Papers ded. Prof. A. Krogh.) Copenhagen.

— 1927: Undersøgelser over østersens biologi II—IV. (Rep. Dan. Biol. Stat. 33.) Copenhagen.

H. M. Vernon, 1895: The respiratory exchange of some lower marine invertebrates. (Journal of Physiology 19.)

XXI. *C. G. Joh. Petersen:* Valuation of the Sea. II. The Animal Communities of the Sea Bottom and their importance for marine Zoogeography. With 6 Plates, 3 Charts and an Appendix. 110 pp. 1913.

XXII. I. *P. Boysen Jensen:* Studies concerning the organic matter of the Sea Bottom. II. *H. Blegvad:* Food and Conditions of Nourishment among the Communities of invertebrate animals found on or in the sea bottom in Danish waters. III. *C. G. Joh. Petersen:* The Work of the Biological Station from 1889—1914. With Illustrations and Tables. 88 pp. IV. *The same:* Appendix to Report XXI. With 2 Charts. 7 pp. On the distribution of the Animal Communities on the Sea Bottom. 1914.

XXIII. *C. G. Joh. Petersen:* On the Animal Communities of the Sea Bottom in the Skagerak, the Christiania Fjord and the Danish waters. With one Chart and four Tables. 29 pp. 1915.

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XXIX. *C. G. Joh. Petersen:* On the Stock of Plaice and the Plaice Fisheries in different Waters. With 2 Charts and 1 Appendix. 42 pp. 1922.

XXX. *R. Spärck:* Studies on the Biology of the Oyster *(Ostrea edulis)* in the Limfjord, with special Reference to the Influence of Temperature on the Sex Change. 80 pp. 1925.

XXXI. I. *C. G. Joh. Petersen:* The Influence of Fishing upon the Stock of Plaice in the Baltic during recent Years. — II. *R. Spärck:* Investigations on the Size of the Stock of Oysters in the Limfjord 1924. — III. *C. G. Joh. Petersen:* Report to the Ministry of Agriculture concerning increased Motor-Fishing in the Limfjord. — IV. *H. Blegvad:* Continued Studies on the Quantity of Fish-Food in the Sea Bottom. — V. *R. Spärck:* A Comparison between the Danish Oyster-Beds and those in Holland and the South-West of France. 63 pp. 1925.

XXXII. *H. Blegvad:* On the Renewal of the Stock of Plaice in the Baltic proper. 37 pp. 1927.

XXXIII. I. *A. C. Johansen:* On the Fluctuations in the Quantity of Young Fry among Plaice and certain other species of fish, and causes of the same. With 7 figures and 1 table. — II. *A. C. Johansen:* On a Spawning Place for winter spawning Herring in the northern part of the Belt Sea. With 2 figures. — III. *H. Blegvad:* On the Annual Fluctuations in the Age-composition of the stock of Plaice. With 2 figures. — IV. *R. Spärck:* Studies on the Biology of the Oyster *(Ostrea edulis)* II—IV. 65 pp. 1927.

XXXIV. I. *R. Spärck:* Studies on the Biology on the Oyster (*Ostrea edulis*) V. — II. *Aage J. C. Jensen:* Remarks on the Hydrography of the Limfjord. With 10 figures and 1 table. — III. *H. Blegvad:* Quantitative Investigations of Bottom Invertebrates in the Limfjord 1910—1927 with Special Reference to the Plaice-Food. With 2 figures and 2 tables. — IV. *A. C. Johansen:* The Extent of the Annual Transplantations of Plaice in the Limfjord and the Yield resulting therefrom. With 11 figures and 12 tables. — V. *Aage J. C. Jensen:* The Relation between the Size of the Plaice Stock and the Quantity of "First Class Plaice-Food" in certain Parts of the Limfjord. With 3 figures and 2 tables. — VI. *Erik M. Poulsen:* The Haddock in the Belt Sea and the Western Baltic during the Years 1926—28. With 4 figures and 8 tables. 125 pp. 1928.

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